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PRECIOUS STONES.

BY GEORGE F. KUNZ.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *February 17, 1890.*]

The Lecturer was introduced by Prof. PERSIFOR FRAZER, of the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, AND LADIES AND GENTLEMEN:

The lecture this evening, aside from some general descriptions, will consist of a synopsis of some recent information on the subject of gems, precious and ornamental stones—in other words, the more important discoveries that have been made and the changes that have taken place during the past ten years; together with a few notes on the precious stones exhibited at the Paris Exposition.

What is a precious stone? The answer to this question is not easy; for the value of a particular kind of stone is often due in great measure to the caprice of fashion

or to some adventitious circumstance of time or place; and some stones that are to-day of small value have, during certain periods in the past, almost displaced the diamond or the ruby in public estimation. Beauty of color, hardness and rarity are the essential qualities which entitle a mineral to be called precious. Strictly speaking, the only precious stones are the diamond, ruby, sapphire and emerald, though the term is often extended to the opal, notwithstanding its lack of hardness, and to the pearl, which is not a mineral, but strictly an animal product.

Popularly, a gem is a precious or semi-precious stone, when cut or polished for ornamental purposes. Mineralogically, the term designates a class or family of minerals hard enough to scratch quartz, without metallic lustre, but generally brilliant and beautiful, and includes the semi-precious or fancy stones (called pierres de fantasie by the French), such as the chrysoberyl, alexandrite, tourmaline, spinel, topaz, garnet and amethyst. Archæologically, the term is restricted to engraved stones, such as intaglios and cameos. The term jewel is applied to a gem only after it has been mounted.

The epithet phenomenal is used in regard to stones which exhibit an unusual or singular play of color, such as opal, moonstone, sunstone and Labrador spar; or which change their color by artificial light, like alexandrite; or show a line or band or bands of light, as the line in the cat's-eye and the star in the sapphire and ruby asteria.

Before mineralogy became the exact science that it is to-day, and even at the present time, precious stones were determined only by the eye; hence, in ancient times, they were confused with one another, as unfortunately they are sometimes in the present age; so that the ruby, spinel, garnet and rubellite were all probably known as carbuncle, and the yellow sapphire, yellow topaz, yellow quartz, yellow zircon and yellow tourmaline were all known as topaz.

At present, however, the eye, which is not always accurate, is not alone depended on. Specific gravity and certain other methods are now employed in the exact determinations of precious stones. First, by specific gravity occa-

sionally by means of solutions (such as Sonstadt's or Thoulet's solution, the double iodide of potassium and mercury) which can be made to vary from over three times the weight of water to the specific gravity of the gem lowest in the scale; again, by the aid of the scale of hardness, the diamond being ten, sapphire nine, topaz eight, quartz seven, feldspar six, apatite five, fluorite four, and calcite three. Among optical means, we find the dichroscope of great assistance, as many gems possess dichroitic properties, showing two images of each object viewed, and these differ in color in the various gems; by the use of the spectroscope we find that the ruby gives a bright red band, the garnet a large series of absorption bands, etc. By means of the polariscope, the crystalline system to which the precious stone belongs can be readily determined. By passing a cut stone of yellow or white quartz through the fingers and a yellow topaz of the identical shade of the quartz, we find that the topaz is slippery, while the quartz offers considerable resistance. Certain gems are electrical, notably so, amber, tourmaline and topaz, the latter retaining this property for some time after heating.

The diamond crystallizes in the isometric system, and is usually found as an octahedron or as some modification of that form. It is ten in the scale of hardness, and is the hardest of all known substances. Its composition is pure carbon. It has a greater refractive and dispersive power on light than any other gem, and is the only one that is combustible. Its specific gravity is about 3·525. In color, its range is extensive, it having been found in almost every color of the spectrum, though more commonly white, yellow, brown; rarely rose-red, red, blue, and green.

An impression seems to prevail that a diamond will not break if struck with a hammer on an anvil, and more than one fine stone has been shattered in attempted tests, thus proving the fallacy of the assertion. While the diamond is very hard, it is also very brittle, and can be easily broken; and although every substance, from the hardness of feldspar up, including a cleavage or cut diamond, will scratch

glass, nothing but the natural edge of a diamond crystal will cut it. If a stone will scratch corundum, and is not scratched by a diamond, it is safe to assume that it is a diamond. It is well to make the trial on a smooth or polished surface, otherwise the scratch will not be perceptible.

The author of the *Arabian Nights* undoubtedly thought he was imagining the wildest and most improbable things when he wrote of Sinbad the Sailor's obtaining his treasures in the Valley of Diamonds; yet the African mines have paled this profusion of wealth into utter insignificance. A glimpse of these new Valleys of Diamonds may prove interesting. Before the opening of the South African mines, the primitive method of washing diamonds was carried on by thousands of slaves, who, like those who built the pyramids under the lash of the Pharaohs, simply obeyed a master who mercilessly goaded them on, whip in hand. This method is, to-day, replaced by the most ingenious and powerful machinery, which, eyeless though it be, allows fewer diamonds to escape than would the keenest and most disciplined army of washers.

At the Kimberley Diamond Mines, in South Africa, wonderful progress has been made in the last decade. About 1877, the work of consolidation of the different companies began. Originally, the mines were worked as 3,238 separate claims, each thirty-one feet square, separated by a seven-and-a-half-foot roadway.

A mine in the early days was a bewildering sight. Miles of wire cables were stretched across it in all directions, and to these were attached the buckets for carrying the earth, reef, or wall-rock of the mines, or, at times, water, and all running from individual claims. Some of these latter were almost level with the surface, while others next to them might be cut down 200 feet, and others only 100 feet, yet all were worked independently. At the sides were endless belts, with pockets for carrying the earth. The result of this independent system of working was that rock was dropped so recklessly that, it is said, the vicinity of the claims was as dangerous as a battle-field. The loss of life was great, not from this source only, but also from the fall-

ing of immense masses of reef, loosened by the blasting, which several times buried a score of men at once. But improved methods were gradually introduced. Steam railroads were run down into the mine, and parts of it were levelled. Millions of tons of reef required moving, and millions of gallons of water required to be pumped to the surface; the only way to do it was to assess every company in the mine proportionally. Many mistakes were made at first, if mistakes they can be called, when the problems offered for solution were entirely new and untried. The yellow or surface soil which overlaid the blue stuff pulverized so readily that it could be taken to the washing machine directly, but as the claims were sunk down in the blue earth, the rock grew harder, and dynamite became necessary. Immense quantities of it are now used for blasting. On January 10, 1884, through carelessness, thirty tons of dynamite and ten tons of blasting-powder and gelatine, in all worth $80,000, exploded with terrific effect; the smoke column was 1,000 feet high, and visible at the River Diggings, thirty-five miles distant.

After the earth "blue," as the diamond rock is called, is raised, it is put on the sorting ground, where it is partly disintegrated by water and the action of the atmosphere. It is then broken by hand and taken to the "compound" or diamond sorting machine, a large machine into which the rock is thrown from the sorting and breaking floors. It is here broken into still smaller fragments and then passed down into large vats, containing immense centrifugal wheels, on which, as they rapidly revolve, the rock is finely divided. The lighter materials, such as altered olivine, quartz, mica and mud are then floated out, while the diamonds, garnets (some of which are exceedingly rich in color and of large size, are sold under the name of cape rubies,) and other heavy minerals are concentrated together in the lowest part of the "compound." So carefully is the rock and earth washed that all the diamonds down to the size of a pinhead are saved.

Since great depths have been reached, and even before, the recent consolidation became an absolute necessity to work the mines.

A prize of £5,000, offered for the best tunnel or shaft system for use at the Kimberley Mines, was awarded to the Jones system, which is sunk on the coffer-dam principle. At present there are many shafts and inclined planes in the Kimberley Mine alone, all sunk at some point in the reef outside of the mine. From 11,000,000 to 13,000,000 gallons of water were annually hoisted from the Kimberley Mines, at a cost of sixpence per load of 100 gallons.

Five years ago, in addition to many miles of aërial tramways, there were over 170 miles of tramway around the four Kimberley Mines; while 2,500 horses, mules, and oxen, and 350 steam-engines, shafts, etc., representing 4,000 horse-power, were employed in the work. One million pounds sterling were annually expended for labor, and over £1,000,000 for fuel and other supplies. The gross capital of the companies was then nearly £10,000,000. Over 10,000 natives, each receiving £1 a week, and 1,200 European overseers, at an average wage of £5, were employed.

The supposition so long talked of, that a unification would ultimately be accomplished, and the diamond mines consolidated into one gigantic trust for the regulation of prices and production has been realized, the DeBeer's Mine Company having absorbed so many companies during 1888 and the early part of 1889, that they control the output of mines which yield twenty-nine–thirtieths of all the diamonds in the world. As a result, they have limited the production. The cost of mining having become necessarily higher, as it was carried to greater depths and larger dividends were required to pay the interest on the stock of the DeBeer's Mining Company, which now amounted to between £18,000,000 and £20,000,000; cut diamonds have therefore advanced twenty-five per cent. in value during the last nine months of 1889, and the price is not likely to recede. The advance of twenty-five per cent. on the cut stones is equal to nearly seventy-five per cent. on the rough material. One effect of the increased price of rough stones and the limitation of the output, has been that some thousands of diamond cutters have been thrown out of employment at Antwerp and Amsterdam.

On the other hand, one benefit of the consolidation has been the introduction of what is known as the compound system, by which the "boys," as the miners are called, are housed and fed under contract for a certain term, provided with amusements and liquor, and thus kept apart from the influences of the vicious whites, who instigate them to crime in their "canteens," as the groggeries are called which are maintained by the I. D. B.'s. It became a question at one time whether the mines could be profitably worked, when from one-fifth to one-quarter of all the yield, it was estimated, never reached the proper owners, as the native diggers swallowed and concealed the diamonds in every possible way. It became necessary for the companies, in self-defence, to take extraordinary precautions against this great loss. Overseers or special searchers were appointed, who made the most thorough examination of all who left the mines. The natives use most ingenious methods for the concealment of the gems. On one occasion some officers, suspecting that a Kafir had stolen diamonds, gave chase, and caught up with him just after he had shot one of his oxen. No diamonds were found upon the Kafir, it is needless to say, for he had charged his gun with them, and after the disappearance of the officers, he dug them out of his dead ox. Diamonds have been fed to chickens; and a post-mortem examination a few years ago held over the body of a Kafir revealed the fact that death had been caused by a sixty-carat diamond which he had swallowed. Early in the history of the mines a detective force, consisting of men, women, and children, was formed, and the severest punishment is still inflicted on transgressors of the Diamond Act.

None but those authorized by the law, termed patented agents, less than fifty in number, are allowed to purchase or even to possess rough diamonds at Kimberley. The loss would not have been so great but for the irregular diamond I. D. B.'s, as the "fences" are called, who lowered the price of stones by underselling the companies in the London market.

More diamonds weighing over seventy-five carats each after cutting have been found since the African Mines were

opened, than were known before. The most important one found in South Africa is the Victoria diamond or Imperial diamond, as it is called. The original crystal weighed 457½ carats, or over three ounces Troy. Strange to say, although this is the largest diamond of modern times, its early history is very obscure. It is reported that the stone was found in the Kimberley Mines in the month of July, 1884, by a surveillance officer, and by him sold to some illicit diamond buyers, and afterward to a syndicate of European dealers. The stone has been cut, and in its finished condition weighs 180 carats. It is a beautiful, perfect, "steel-blue" diamond, and the largest white brilliant known, and is valued at $200,000. Among some other large diamonds may be mentioned the Du Toit, which weighed 244 carats when found; the Jägersfontain, 209¼ carats; the Stewart diamond, weighs 260 carats; the Tiffany yellow, weighing 125⅜ carats after cutting; the great Orange, 110 carats; the Porter Rhodes, weighing sixty-eight carats after cutting; the Dudley forty-six and one-half carats, and a number of others.

Thirty-eight million carats of diamonds, weighing over nine tons, have been found here. In the rough, their aggregate value was $250,000,000, and after cutting nearly $600,000,000, which is more than the world's yield during the preceding two centuries. Of the whole production, not more than eight per cent. can be said to be of the first water, twelve per cent. of the second water, and twenty-five per cent. of the third, while the remaining forty-five per cent. is called bort, a substance which, when crushed to a powder, is of use in the arts for cutting hard substances and for engraving. This must not be confounded with the bort carbon (carbonado) found in Brazil, an uncrystalline form of the diamond which from its amorphous structure is adapted for use in drills, for boring and tunnelling rocks, etc., and has never yet been found in South Africa. It is worth from six to ten times as much as bort.

An English company has recently been formed, under the name of the Hyderabad Mining Company, to work the mines in India, where it is thought that the famous Kohinoor diamond was found.

India and Borneo are now yielding very few diamonds, less than one per cent. in all of the entire product. These two countries, together with Brazil, yield probably less than five per cent. of the total output.

Diamonds have been found in the tertiary gravels and recent drifts near Bingera in Inverell, Australia; also along the Cudgegon River, 160 miles northwest of Sydney, and in other districts in Australia. The colors are white, straw, yellow, light brown, pale green and black. The largest stones yet found were cut into gems weighing three and one-half and three carats, respectively. A trial made by the Australian Diamond Mining Company produced 190 diamonds, weighing 197¾ carats, from the washing of 279 loads of earth, These Australian fields can scarcely be called productive as yet, nor from present appearances do they seem likely to become formidable competitors of the South African fields.

About twelve years ago, it was suggested by Messrs. Dunn, Cohen, Huddleston and Prof. Rupert Jones and others, that the South African diamonds were formed in a sort of volcanic mud. Mr. Huddleston thought that the action was hydrothermal rather than igneous, the diamonds being the result of the contact of steam and magnesian mud under pressure upon the carbonaceous shales; he compared the rock to a boiled plum pudding.

At a meeting of the Manchester Literary and Philosophic Society, held October 21, 1884, Prof. H. E. Roscoe presented a paper on the diamond-bearing rocks of South Africa, in which he said that he had noticed a peculiar odor, somewhat like that of camphor, evolved on treating the soft "blue" diamond earth with hot water. A quantity of this earth he powdered and digested with ether and on filtering and allowing the ether to evaporate, he obtained a small quantity of a strongly aromatic body, crystalline, volatile, burning easily with a smoky flame, and melting at about 50° C. Unfortunately, the quantity obtained was too small to admit of a full investigation of its composition and properties. He suggested that perhaps the diamond was formed from a hydrocarbon simultaneously with the aromatic body.

The late Prof. H. Carvill Lewis, at the British Associa-

tion Meeting, September, 1886, read a paper on the genesis of the diamond, in which he stated that from the DeBeer's Mine, at a depth of 600 feet, he had obtained specimens of rock which were unaltered, and proved to be a peridotite containing carbonaceous shale. He added that from information he had received from New South Wales, Borneo, and Brazil, he then believed that all diamonds were the result of the intrusion of a peridotite through carbonaceous rocks and coal seams.

The similarity of the South African peridotite to a peridotite, described by Mr. J. S. Diller, in Elliott County, Ky., led Prof. Lewis to suggest interesting possibilities there, and through the invitation of Prof. Proctor, of Kentucky, Major Powell sent Mr. J. S. Diller and myself to examine this Kentucky peridotite. Although the associated minerals were identical with those accompanying the diamonds, *i. e.*, of South Africa—pyrope garnet, ilmenite, biotite, pyroxene among others being present—yet by analysis of the enclosed carbonaceous shales, from which it was believed that the diamond is formed, it was found that the Kentucky shale contained only ·681 of carbon, while the South African contained thirty-five per cent., and could be readily ignited with a match. Hence, unless the peridotite has penetrated the older and richer Devonian shales, the probability of finding diamonds there has been considerably weakened by the investigation.

The occurrence of diamonds in the United States is chiefly confined to two regions, geographically very remote and geologically quite dissimilar. The first is a belt of country lying along the eastern base of the Southern Alleghenies, from Virginia to Georgia, while the other extends along the Western base of the Sierra Nevada and Cascade ranges in Northern California and Southern Oregon. In both cases, the mode of occurrence has several marked resemblances. The diamonds are found in loose material, among deposits of gravel and earth, and are associated with garnets, zircons, iron sands, monazite, anatase, and particularly with gold, in the search for which they have usually been discovered. This resemblance is due altogether to the

fact that these loose deposits, in both regions, are merely the débris of the crystalline rocks of the adjacent mountains and therefore present a general similarity, while the ages of the rocks themselves are widely different.

The finding of a twin crystal of diamond, weighing four and one-third carats, at Dysortville, N. C., of a three-carat stone near Atlanta, Ga., and of a three-eighths-carat stone at Montpelier, Adair County, Ky., are worthy of mention in connection with the finding of diamonds in the Southern States.

Ten years ago, $100,000 was an unusual amount for even the wealthiest to have invested in diamonds; whereas, to-day there are a number of families each owning diamonds to the value of $500,000. Ear-rings worth from $5,000 to $8,000 a pair excite no wonder to-day; formerly, they were seldom seen. Of the French crown-jewels sold in Paris, May, 1886, more than one-third, aggregating over $500,000 in value, came to the United States.

IMPORTS OF DIAMONDS INTO THE UNITED STATES.

From the customs import lists, after deducting the approximate value of cut stones other than the diamond, we find that import duty was paid on about $120,000,000 worth of cut diamonds in the last twenty-four years, of which $90,000,000 worth were imported during the last twelve years. In 1868, $1,000,000 worth were imported, and about $1,200,000 worth in 1867, but about $11,000,000 in 1888, and the same amount in 1889, or ten times as many in the latter year as twenty years previous, showing the increase of wealth and the great popularity of the diamond among Americans, the previous figures representing the import prices, exclusive of mounting or dealers' profits. A single firm at present sells yearly more than the annual import of 1867.

The expression "first-water," when applied to a diamond, denotes that it is free from all traces of color, blemish, flaw or other imperfection, and that its brilliancy is perfect. It is, however, frequently applied to stones not quite perfect, but the best that the dealer has, and they may be of

only second quality. It is almost impossible to value a diamond by its weight only. Color, brilliancy, cutting and the general perfection of the stone have all to be taken into account. Of two stones, both flawless and of the same weight, one may be worth $600, and the other $12,000. Exceptional stones often bring unusual prices, while off-colored stones sell for $60 to $100 a carat, regardless of size. The poor qualities have depreciated so much in value that some are worth only from one-tenth to one-fourth what they were worth twenty years ago. This is specially true of large stones of the second or third quality.

The names ruby, sapphire, Oriental amethyst, Oriental emerald and Oriental topaz are given to the transparent red, blue, purple, green and yellow varieties, respectively, of the mineral corundum. These colors are supposed to be due to the presence of minute quantities of metallic oxides. The specific gravity of corundum varies from 3·98 to 4·05; its hardness is nine. The finest pigeon-blood-colored rubies are found at Mandalay, in Burmah, and when fine command from five to ten times the value of diamonds of equal weight. Fine rubies, generally small, sometimes of a pink color, and often with a currant-wine or purplish tint, are found at Ratnapoora, Ceylon; likewise in Siam, where, however, the color is commonly a dark red, almost that of a garnet, and, like it, with a tinge of brown. The finest sapphires are found in Burmah and Ceylon; in the latter, some of the finest corn-flower blue varieties occur. Many of the rich velvety blue, as well as the lighter-colored stones are from the Simla Pass in the Himalayas. Fine sapphires have recently been found in Siam; and in Australia they occur of an opaque, milky-blue color.

Dr. William Crookes, after an elaborate series of experiments with all colors of corundum in sealed tubes, believes that the various colors are only modifications or allotropic forms of the same substance; and that since all the colors of corundum phosphoresce with the same range of colors in the phosphorescope, he suggests that there is no coloring matter.

The acquisition of the Burmese Ruby Mines cost the

British Government a vast sum of money. On the wars of 1826 and 1852 England expended $75,000,000 and $15,000,000, respectively; and after all this sacrifice of treasure the Burmah and Bombay Trading Company claimed, four years ago, that King Thebaw, of Burmah, had arbitrarily cancelled the leases by which the company controlled the output of the ruby mines near Mandalay.

The war of 1886, which followed, involved the raising of an army of 30,000 men and an outlay of $5,000,000, but the British Government gained control of the long-coveted ruby mines.

The question which next presented itself was, how should they be worked? Several firms were desirous of securing the lease, and after the Indian Government had virtually closed a lease to Messrs. Streeter & Co., the London jewellers, at an annual rental of four lakhs of rupees (£40,000) for a term of five and a half years, it was at first revoked, but after a time was given to Messrs. Streeter & Co., who organized the company known as the Burmah Ruby Mines (Limited), and sent a force of engineers and a quantity of machinery to Burmah. This year will determine whether or not the mines are as rich as they were supposed to be, and whether the ruby will still retain its place as the most costly of precious stones.

The ruby mines of Burmah are situated in the valley of Magok, fifty-one miles from the bank of the Irrawaddy River and about seventy-five miles north of Mandalay, at an altitude of 4,200 feet. Concerning these mines very little was known, as they were always the monopoly of the crown and were jealously guarded. It was said that they paid King Thebaw's Government 100,000 rupees per annum and one year 150,000 rupees. Mining was carried on by forty or fifty wealthy natives, who employed the poorer townspeople at liberal wages; but at present only seventy-eight mines or diggings are in operation. All the gems were sent to Ruby Hall, Mandalay, to be valued.

One thing at least we learned from the British occupation of Burmah, namely, that King Thebaw did not own the dishes of rubies which were said to rival anything known.

An examination of the jewels, now deposited at the India Museum at South Kensington, proved that there was only one cabochon ruby of fair, not fine quality, and several polished sections of a large inferior crystal of emeralds of any value in his entire crown jewels.

In 1882, a very remarkable discovery of sapphire was made in the Zenskar range of the Northwestern Kashmir Himalaya, near the line of perpetual snow. A landslide removed an abundance of sapphires which were first used as gun-flints by the natives. One writer speaks of having seen about a hundredweight of them in the possession of a single native. Traders, however, soon carried them to the distant commercial centres, where their value became known. There was an instant rush ot jewellers' agents to the locality of the mine; and the price rose rapidly until about £20 per ounce was paid for the rough sapphires as found. The Maharajah, of Cashmere, promptly exercised his authority, and sent a regiment of Sepoys to take possession of the mines and harry the natives who were suspected of having stones in their possession or any knowledge of new localities where the gems could be found. Any one who had money was suspected either of having sold sapphires or of being about to purchase them, and was despoiled or even imprisoned. This naturally enough had the effect of compelling secrecy. Several crystals were found weighing from 100 to 300 carats each. During the first year of the discovery, the Delhi jewellers are said to have bought up sapphires to the value of £20,000.

The effect of this discovery was to lower the prices, for a time only, however.

Public interest in semi-precious stones has increased greatly during the last ten years. Formerly jewellers sold only diamonds, rubies, sapphires, emeralds, pearls, garnets and agates; but at present it is not unusual to have almost any of the mineralogical gems, such as zircon, asteria or star sapphire or star ruby, tourmaline, spinel or titanite called for, not only by collectors, but by the public, whose taste has advanced in the matter of precious stones, as well as in the fine arts.

This change may be partly attributed to the fact that since the Centennial Exhibition, art has received more attention among us than ever before. The Duke of Connaught's giving his bride a cat's-eye ring as an engagement token was enough to make that stone fashionable, and to increase its value greatly. The demand soon extended to Ceylon, where the true chrysoberyl cat's-eye is found, and stimulated the search for these stones there. In the chrysoberyl cat's-eye the effect is the result of a twinning of the crystal, or a deposit between its crystalline layers of other minerals in microscopie inclusions; so, that if the stone be cut across these layers *en cabochon*, or carbuncle-cut, as it is called, a bright line of light will be condensed on the dome-like top of the stone.

In the search for these chrysoberyl cat's-eyes, there has been found an endless series of chrysoberyls of deep golden, light yellow, yellow-green, sage-green, dark-green, yellowish brown and other tints. They are superb gems, weighing from one to 100 carats each, and rank next to the sapphire in hardness. It was a great surprise to the gem dealers to find that the darker leaf-green or olive-green stones possessed the wonderful dichroitic property of changing to columbine red by artificial light, which entirely subdued the green tint, and gave the red predominance. These were in fact alexandrites, stones which had formerly been found only in Siberia, and even there of but poor quality. Though found in large crystals, a perfect gem of even one carat was a great rarity. Here, however, were found fine stones, weighing four carats and upwards, and one exceptionally fine one weighing nearly seventy carats. These can be numbered with the most remarkable gems known. Strange to say, among this variety a few specimens have been found which combine the characteristics of both the cat's-eye and the alexandrite, and are called alexandrite cat's-eyes.

Moonstones, also from this same Province of Kandy, Ceylon, were brought to light by this search for cat's-eyes. It would not be an over-estimate to say that 100,000 of these stones have been sold here in the last four years. They

vary in size from one-eighth of an inch to nearly two inches in length, and many of them surpass anything hitherto known of their kind in beauty and size. Those that display the chatoyant and the opalescent blue color are especially beautiful.

The demand for cat's-eyes also brought into request the then rare mineral from the Orange River, South Africa, known as crocidolite, especially that variety that had been altered to a quartz cat's-eye or tiger-eye, as it is called. In this stone an infiltration of silicious water has coated each fibre with quartz or chalcedony, giving it the hardness of seven. This then pleasing stone readily sold for $6 a carat, and at the outset for even more: but owing to the excessive competition of two rival dealers, who sent cargoes of it to the London market, the price fell to $1 or even to twenty-five cents per pound by the quantity. Even table-tops have been made of this material by veneering. Vases, cane-heads, paper-weights, seals, charms, etc., were made of it and sold in large quantities. Burning it produced a bronze-like lustre, and by dissolving out the brown oxide-of-iron coloring, an almost white substance was obtained, which was dyed by subjecting it to the action of red, green, and brown-colored solutions, these colors, owing to the delicacy of the fibres, were evenly absorbed. A material unknown ten years ago is to-day found at every tourist's stand, whether on the Rigi, on Pike's Peak, in Florida, at Los Angeles, or at Nijni Novgorod, and sold under a variety of names, showing how thoroughly organized is the system of distribution in the gem market. Missionaries have never spread a religious belief as rapidly as traders have disseminated the tiger eye.

Since it has become generally known that Queen Victoria is partial to the opal, the old and stubborn superstition concerning it, which is said to date from Scott's "Anne of Geierstein," has been slowly yielding, until now the gem has its share of popular favor. During the last two years, ten times as many opals have been imported as were brought here during the preceding decade. Mexican fire-opals are much more common, as those tourists know to

their sorrow who buy these stones at exorbitant prices in Mexico, hoping thus to pay the expenses of the trip, until they find on reaching New York, that they are worth only about one-quarter of what they paid for them. The principal opal mines of Mexico are situated on the Hacienda Esperenza, near Queretera; and it is believed that a demand of 100,000 stones per annum could be supplied without raising the price perceptibly, though in the market of precious stones the demand generally raises the price.

The finest opals are from the mines of Dubreck, Hungary, which, although they have been worked for three centuries, still yield the government a revenue of $6,000 annually. The output is so carefully regulated that the market is never glutted. In Australia large quantities of opals have been found differing from the Hungarian and yet often quite as beautiful.

About ten years ago a new and very interesting variety of opal was brought from the Baricoo River, Queensland, Australia, where it is found in a highly ferruginous jasper-like matrix, sometimes apparently as a nodule and then again in brilliant-colored patches, or in specks affording a sharp contrast with the reddish-brown matrix, which admits of a high polish and breaks with a conchoidal fracture. Many of these stones are exceedingly brilliant. They are of the variety known as harlequin opals, their color being somewhat yellow, as compared with the Hungarian stone, although not less brilliant. The rich ultramarine blue opal in quite peculiar to this locality. A company (capital $200,000) has been formed, and the gems are about to be extensively mined. This stone is especially adapted for curious cameo-like objects, such as faces, dogs' heads, and the like, made by cutting the matrix and the opal together.

In 1877, F. Pisani, of Paris, described a transparent golden-yellow spodumene, which has been found in Brazil and was supposed to be chrysoberyl. Strange to say, a little later a yellow-green variety associated with emerald-tinted beryl crystals, the latter called "green bolts" by the farmers, was obtained by Mr. J. A. D. Stephenson, of Statesville, N. C., who brought it to the attention of the

northern mineralogists, Norman Spang, Dr. F. A. Genth and W. E. Hidden. The latter sent a specimen of this mineral, which he supposed to be diopside, a variety of hornblende, to Dr. J. Lawrence Smith, of Louisville, Ky., who found upon analysis that it was a transparent spodumene instead of diopside, as had been supposed, and named it Hiddenite. This locality has furnished several dozen crystals of the finest emeralds (of little value as gems, however,) that have ever been found anywhere. Among them is a crystal eight inches long and another weighing eight and three-quarter ounces, valued at $1,000. Both of these, together with many other fine minerals found here, are in the famous cabinet of Mr. Clarence S. Bement, of Philadelphia, the finest private collection of minerals in the world.

At Stoneham, Me., was found the finest aquamarine on this continent, weighing 125 carats, as well as many other fine stones, weighing in all some hundreds of carats. Some fine transparent yellow beryls were found at Albany, Me.; at the Avondale quarries in Delaware County, Pa., several twenty carats golden-yellow beryls and many smaller ones have also been found; and at a mica mine, near Litchfield, Conn., several thousand dollars' worth of this gem have been obtained. Amelia County, Va., and several localities in North Carolina have also afforded good specimens.

On Mt. Antero, Col., at an altitude of 14,000 feet, nearly on the line of perpetual snow, there have been found (associated with phenacite) some beautiful beryls, clear enough to afford a number of fine gems of good blue and green color.

In 1882, topaz was first found in Colorado, and since then it has been found in some abundance at Platte Mountain, Cheyenne and at Crystal Peak, near Pike's Peak. Many of the crystals are remarkable for their size, several of them weighing over a pound each. The smaller ones are transparent and range in color from pellucid white to rich cinnamon-brown. Some few are light blue and light green. The two larger gems weigh 125 and 193 carats, respectively, and equalled those from any known locality, but $3,000 would

probably be a fair estimate of the value of all that have been found there.

At Stoneham, Me., and at North Chatham, a town adjoining in New Hampshire, topaz, as well as phenacite, was found, the latter transparent enough to cut into gems. A few crystals of topaz, measuring one foot on a face, were also found, and a number of smaller ones, of little value as gems.

The Mount Mica Mining Company, of which Dr. A. C. Hamlin of Bangor, Me., is the organizer and President, began operations at the famous tourmaline locality, Mount Mica, near Paris, Me., in 1879, and prosecuted the work for three summers. There were found here very beautiful tourmaline crystals, and some of the finest known examples of this gem. A crystal of blue tourmaline, measuring nine inches, and a green tourmaline, ten inches long, were among the most remarkable finds, the proceeds of which altogether have amounted to something over $5,000.

At Auburn, Me., hundreds of crystals of tourmaline have lately been found, some of which have been cut into gems, though they do not approach in perfection those from the more famous Paris locality. In color, they are generally light green, light blue and light red.

Five years ago, the existence of rock-crystal of any size was almost unknown in the United States; but about that time, a large, clear mass, weighing some twelve pounds, which had been found in Alaska, was brought to New York City, and made into thin slabs for hand-mirrors. In 1885, a fifty-one-pound fragment, said to have been broken from a crystal which originally weighed 300 pounds, was found in Chestnut Hill Township, Ashe County, N. C. On visiting the locality, I found that most of the crystals there were obtained either by digging where one crystal had been found or by driving a plow until crystals were unearthed. Several dozen crystals in all have been found here, one mass of twenty pounds being almost absolutely pure. Some of the clearer masses have been cut into vindigrettes, bonbon boxes, clocks and other art objects and exhibited at the Paris Exposition.

Prof. R. B. Riggs, of the laboratory of the United States Geological Survey, recently made over twenty-five analyses of the tourmalines of all colors. He found the question of the color of the lithia tourmaline a very interesting one. The color of the iron and magnesian varieties depends on the amount of iron present, ranging from the colorless De Kalb variety through all the shades of brown to the Pierrepont black crystals, while the lithia tourmaline, containing more or less manganese, gives us the red, green and blue, as well as colorless varieties. The shades of color do not depend on the absolute amount of manganese present, but rather on the ratio existing between that element and the iron. Thus, when the amounts of manganese and of iron are equal, we have the colorless, pink or very pale green tourmaline. An excess of manganese produces the red varieties; and if the iron is in excess, there result the various shades of green and blue.

Turquoise, found in Los Cerrillos, N. M., where it had been worked for years before the arrival of the Spaniards, has recently been identified in Arizona, Colorado and Nevada. Although not of much value as an ornamental stone, it recommends itself for ornamental purposes.

The agatized or jasperized wood of Arizona, the existence of which has been known for thirty years, has only been utilized in the arts during the last four or five years. This material exists in immense quantities, in compact tree sections from one foot to four feet in diameter, and presents the most beautiful shades of yellow, red, brown, white and black, generally mottled, the colors all blending imperceptibly and thus producing a pleasing and harmonious effect. It has been successfully cut and polished by the Drake Company, of St. Paul, Minn., who saw and polish large surfaces of hard material better than can be done anywhere else. Its extreme hardness and its richness of color will always recommend it as a high-priced ornamental stone.

A curious white, opaque variety of opal, known as hydrophane, has been found at some Colorado localities. It possesses the remarkable property of displacing twice its bulk of water, and then from opaque white it becomes per-

fectly transparent. The finder proposes the name "magic stone," and suggests its use to conceal photographs, hair, or other objects which the owner wishes to display only as his caprice dictates. This stone is identical with one known as oculus mundi, world's eye, or lapis mutabilis, described by De Boot, De Laet, and Boyle, in the sixteenth century, and which was evidently tabasheer, an organic opal that forms in the joints of the bamboo. It is undoubtedly the snake-stone of the Buddhist priest. Tavernier, in his travels, states that the source of these stones was unknown, but says they clove to the roof of the mouth, and when dropped in water they caused the water to boil—in other words, air in bubbles would leave the stone and would ascend to the top of the water.

What may prove to be of considerable use in the arts, and as an ornamental stone, is the banded jasper, found in Graham County, Kan., which is beautifully banded like an onyx, in red, yellow, brown, white and other colors. Pieces a foot long, and six to eight inches thick, can be taken out. As a banded jasper, it is unrivalled in the whole world.

The small, brilliant rutile crystals from Alexander County, N. C., have furnished perfect black gems, which approach the black diamond more closely in appearance than anything else known.

The well-known labradorite rock of Lewis County, N. Y., is so plentiful that the reflection of the boulders has given the river that runs through the locality the name of Opalescent River. This is being extensively cut as an ornamental stone.

Pearls are lustrous concretions, consisting essentially of carbonate of lime interstratified with animal membrane, found in the shells of certain mollusks. They are believed to be the result of an abnormal secretory process caused by an irritation of the mantle of the mollusk, consequent on the intrusion into the shell of some foreign body, as a grain of sand, an egg of the mollusk itself, or perhaps some cercarian parasite. It has also been suggested that an excess of carbonate of lime in the water may cause the development of the pearl. Accepting the former theory as the

more probable one, it is easy to understand how this foreign body, which the mollusk is unable to expel, becomes encysted or covered as by a capsule, and gradually thickens, assuming various forms—round, elongated, mallet-shaped—and is sometimes as regular as though it had been turned in a lathe. It has been suggested that the mollusk continually revolves the enclosed particle in its efforts to rid itself of the irritation, and that this accounts for its roundness, and that the revolving is due to a natural motion which is accelerated by the intruding body.

In regard to the formation of pearls, the following statements may be made: Whatever the cause or the process of their production, these interior concretions may occur in almost any molluscan shells, though they are confined to certain groups, and their color and lustre depend upon those of the shell interior, adjacent to which they are formed. Thus, the pink conch of the West Indies yields the beautiful rose-colored pearls, while those of the common oyster and clam are dead white or dark purple, according to their proximity to the part of the mantle which secretes the white or the dark material of the shell. The true pearly or nacreous iridescent interior belongs to only a few families of the mollusks, and in these alone can pearls proper be formed at all, while, in point of fact, they are actually obtained only from a very few genera.

According to Dr. William H. Dall, none of the air-breathing mollusks (the land snails) produce a nacreous shell: and among fresh-water mollusks, none are pearl-bearers except certain of the bivalves, notably those belonging to the groups appropriately called the naiades, of which the common river-mussel (*Unio*) is a typical example. The soft internal parts of these mollusks are covered by a thin, delicate membrane, called the mantle, from the surface, and particularly from the outer edges, of which material is excreted to form the inner layers of the shell. The shell consists of two parts, the epidermis and the shell proper, the latter composed of numerous layers. The epidermis, which resembles horn, is chiefly composed of a substance called "conchioline," and is soluble in caustic alkalies.

[*To be continued*]

ELECTRICITY IN WARFARE.

By Lieut. Bradley A. Fiske, U.S.N.

[*A Lecture delivered before the* Franklin Institute, *January 20, 1890.*]

The Lecturer was introduced by Prof. Edwin J. Houston, and spoke as follows:

Members of the Institute and Ladies and Gentlemen:

About four years ago, a lecture was delivered before this Institute on the subject of "Electricity in Warfare." This evening, the endeavor will be made to present the present condition of the art, to show what advance has been made in the intervening years, in what ways electricity is now actually employed, and what is the direction of progress.

At the time of the previous lecture, November, 1885, nearly the whole science was in a transition stage; electricity was just emerging from the laboratory and entering the region of practical life; there was but one war-ship lit by electricity actually at sea, and her plant was so defective and accidents on board from imperfect insulation were so frequent that many concluded that the only effect of her electric equipment was to prove the impracticability of the attempt.

ELECTRIC LIGHTING FOR WAR-SHIPS.

Much of that lecture was devoted to maintaining the advantages of electric lighting for ships; now it will be unnecessary to do more than to say that every war-ship possessing any pretensions whatever to modern equipment is lighted by electricity.

SUBMARINE MINES.

As mentioned in my previous paper, the first practical plan for employing electricity in warfare was proposed and executed by Col. Samuel Colt, and embodied what is now called the submarine mine, or stationary torpedo. During the past five years it cannot be said that very much progress has been made in submarine mining, for it had then reached

a very advanced stage, so that it was practicable to lay out in any harbor a system of electric mines which could be relied upon to blow up any hostile ship trespassing on the premises, and to allow any friendly ship to pass without molestation. Defending a harbor with mines is simply carrying out with more or less elaboration a system by which a large number of water-tight tanks, holding from 100 to 1,000 pounds of gun-cotton or other explosives, are anchored in carefully defined positions and connected by electric cables with protected operating-rooms, in which are batteries, measuring instruments, etc. The more complete mines have usually floating above each of them an automatic circuit closer, in which two contact points are jarred together by a passing ship, and thus afford a passage for the electric current to the fuze in the torpedo. Ordinarily, this current is a weak one, sufficient only to close a relay in the operating-room, which sends in turn another current through a bell or other indicator, but not strong enough of itself to fire the torpedo. But when hostile ships are expected, then the relay is arranged to throw in a strong current, strong enough to heat the fine platinum iridium wire in the fuze, and ignite the fulminate of mercury. This fulminate detonates a primer of dry gun-cotton, and this, in turn, detonates full charge of damp gun-cotton in the torpedo.

SUBTERRANEAN MINES.

Closely related to submarine mines are subterranean mines, which have been used satisfactorily in land warfare, being sown in places over which the enemy might be expected to pass, especially in the approaches to a fort or other intrenched position. The mines may be fitted with percussion fuzes or with electrical connections, such that they can be exploded by an operator within the intrenchments, whenever the enemy arrives at the proper place. The result of the explosion of one of these mines in the midst of an advancing regiment cannot be pictured with comfort. The present system, in which troops are kept in open or skirmish line, rather than closed in mass, will prob-

ably result in a larger number of mines, each mine comparatively small.

SPAR TORPEDO

In my previous paper much space was given to the spar torpedo, in which the explosive was carried on the end of a spar, and was designed to be shoved against the underwater side of a hostile ship. Nothing need now be said about it, except that it is becoming rapidly a thing of the past; perhaps not rapidly enough.

LAY TORPEDO.

With the auto-mobile torpedoes, like the Lay, in which the directing-power, though not the motive-power is electricity, not very much change has come to pass; the torpedo occasionally is exhibited, and shows itself capable of doing good service under certain conditions.

SIMS–EDISON AND HALPINE–SAVAGE TORPEDOES.

In torpedoes, in which the motive-power, as well as the directing-power is electricity, considerable improvement can be seen, notably in the Sims-Edison and the Halpine-Savage. The principal difference between these two types resides in the fact that the power for the Sims-Edison is transmitted to it along the wire, while in the Halpine torpedo it is carried on board in storage batteries. The Halpine torpedo has additional features also, by means of which a projectile can be discharged from the bow, when it strikes any resisting object, such as the underwater body of a ship, or the projecting net, and by which this act of discharge reverses the propelling-motor, thus causing the torpedo to back away from danger. The projectile, meanwhile, keeps swiftly on its way, and when it reaches a certain distance, *i. e.*, the length of a small chain connecting it to the torpedo, it is exploded. The field for torpedoes of this class seems to be the coast, harbors and rivers of a country, rather than the open sea.

WHITEHEAD TORPEDO.

In the practical service of the far-famed Whitehead torpedo, of which there are probably more in existence than

of all others combined, it has been found that electricity gives a more precise control of the time of starting than any other means.

HOWELL TORPEDO.

In the Howell torpedo, which is rapidly coming into prominence as the superior of the Whitehead, it is now contemplated to employ electric motors to produce the rapid revolution of the fly-wheel, which stores up the energy needed for propulsion.

MILITARY TELEGRAPH SERVICE.

In armies, aside from submarine and subterranean mining, the principal use of electricity is in the military telegraph service, and its importance there can hardly be overestimated. One great cause for the suddenness and completeness of the German victory in 1870, was the rapid mobilization of the Prussian Army, and its appearance, on the frontier, ready for battle. Now the splendid efficiency of the telegraph service in the hands of the military authorities made this possible. Nothing is more essential in warfare than despatch and precision in moving the enormous bodies of men, of which armies are composed, with all their ammunition, equipments, supplies and numberless accessories. To move a quarter of a million of men to the frontier in one day means a great deal; and to manœuvre so large a body in the field, with such precision and rapidity that no one division shall have to wait for any other division, simply cannot be done without electricity. In military countries and in all countries during war-time, the regular telegraph lines are pressed into government service; but in the field, these lines must be supplemented by the military telegraph proper. This is a separate organization, with special duties and equipments. Carefully-designed wagons carry wires on reels, batteries, telegraph instruments, telephones, etc. Some of the wire is insulated, and is run rapidly along the ground, just as at a fire a hose is laid in a street from a rapidly-moving hose-cart, some of the wire is bare, is intended to be put on hastily-erected poles and on trees, sheds, etc., or sometimes to be simply laid along the

ground and used in connection with telephones, automatic circuit-breakers and telegraph keys. It is doubtless well-known to all here, that a telephone can be used in this way, even though it occasions a great waste of current, the telegraph key being manipulated in the ordinary way, and the automatic, circuit-breaker, causing a loud sound in the telephone whenever the key is closed.

BALLOON OBSERVATIONS AND BALLOON SIGNALLING.

As part of the military telegraph service, foreign armies have used balloon signalling considerably, and it will probably be an important factor in any future war. The movements of the enemy's forces can plainly be seen from a captive balloon at a height of (say) 1,000 feet, and the result of the observations telephoned down to the officers stationed on the ground. Balloons have also been used in signalling to a distance, an incandescent lamp being suspended beneath, which is made to glow at intervals and to thus signal letters and words in accordance with a preconcerted code.

BALLOON PROPULSION.

As regards balloon propulsion, many experiments have been made, notably by Tissandier, who has accomplished wonders in propelling balloons against the wind, using small storage batteries and very light electric motors. Nevertheless, it cannot be said that the advent of balloon propulsion can be seen anywhere upon the horizon of the future; while, at the same time, the rapid increase of speed and facility in travel, telegraphy, telephony and mail communication, is daily rendering ballooning more and more unnecessary.

INSPECTION OF GUNS.

Among the minor military applications of electricity, there are in use all over the world a number of such devices as small incandescent lamps arranged to illumine the bores of guns, velocimeters, etc., for inspection.

VELOCIMETERS.

Velocimeters are of countless forms, but in all, some kind of time-measuring instrument is set in motion by a

projectile striking one wire and stopped by the projectile striking another wire. The distance between the wires being known, the interval of time recorded is a measure of the velocity of the projectile while passing over that distance. In the same category is an electric chimograph, which records the exact instant a projectile starts and when leaves the bore.

ELECTRIC CONTROL OF WAR-SHIPS.

But it is in the modern war-ship that we find electricity in its broadest field. In no other equal space can there anywhere be found so many, so various and so important forms of apparatus. The reason is apparent. The modern war-ship is the most intricate, tremendous and powerful machine existing. The fate of a nation may, at a crisis, depend upon a single shot. Everything must be done to contribute to her speed, endurance and effectiveness. She must be under quick and absolute control at all instants. She must respond at once to the will of her captain, and her whole strength and power must be his, as though it were a part of him. Ensconced in his conning tower, he must be the brain of the gigantic body. Electric wires must, like nerves, convey instant tidings to him from her innermost recesses, and electric wires flash back from him the inevitable command. The enemy being in sight, the captain must, at each instant, know her exact distance and direction in order that he may lay his guns accordingly. These guns must not be apart from him, under only general control, but he must have them absolutely in his hand, and make them do his will. This does not mean that he must concern himself with details or himself press the key that fires the guns; his gunnery officer, a specialist, can do that; but the gunnery officer must have the proper apparatus under his personal direction, and fire the guns with the precision given him by his skill and experience, and the captain must personally direct the gunnery officer. As for the guns, they must always be bearing on the enemy, and always correctly elevated for the distance, so that they will be ready to fire as soon as they are loaded; no delay can be tolerated.

HANDLING HEAVY GUNS BY ELECTRIC MOTORS.

For quickly bringing heavy guns to point at the target, hydraulic machinery is usually employed in the navies of Europe. But in the U. S. S. *Chicago*, our newest and best cruiser yet at sea, one of the eight-inch guns is trained by an electric motor, and with gratifying results. The gun can be trained much quicker than by hand, but this is not the real element of superiority. The real element is the absolute control possessed by the gun captain. Ordinarily, he is forced to tell somebody else which way to move the gun and how far. With the best drilling and the coolest men, mistakes and delay occur; but with the present apparatus, the gun captain, or second captain, actually moves the gun himself, just where he wants it. Of course, no man is physically strong enough to accomplish this unaided; but the motor aids him almost without his feeling it. A small lever protrudes in rear of the gun, and this lever is so connected with a peculiar switch on the motor, that the gun follows the lever like an obedient child. If the gun captain wishes to move the breech of the gun to go to the right, he moves the lever to the right, as though it were really the gun itself, and the gun immediately moves to the right, slowly or fast, just as the lever moves; and when the lever stops the gun stops; the reverse operation occurs if the lever is moved to the left. It will be seen that this plan dispenses with any arbitrary motions, so that a person entirely ignorant of electricity can control the gun just as well as could Sir William Thomson. The nicest and smallest movements can be obtained, as well as the largest and most rapid, and the big gun, capable of throwing a 250-pound shell nine miles, carrying death and destruction with it, can be handled by a child.

ELECTRIC AMMUNITION HOIST.

But it is not enough that guns be handled with rapidity and precision; they must be supplied with a constant stream of ammunition. The problem of supplying ammunition with sufficient rapidity to carry on a modern engagement, is carrying to the front as one of the most important prob-

lems pressing for solution. The ammunition hoist now on board the *Atlanta* is a step in this direction, furnishing, as it does, a means for raising ammunition to the deck quicker than by hand, with greater safety and with fewer men, thus allowing the extra men to work at the guns. In this hoist, as in the gun-training apparatus, the same idea is carried out—*i. e.*, that of making the electric motor follow the motions of the operator's hand, both in direction and in speed. The operation of turning a wheel or crank causes the switch to start the motor in a certain direction, and the consequent motion of the motor operates to close the switch, so that a race ensues between the operator and the motor. If the operator begins to decrease the speed with which he turns the crank, the motor will overtake him, and will partially close the switch, and the motor will, therefore, lower its speed; whereas, if the operator increase his speed of movement, the switch will thereby be opened farther, and the motor will go faster. The advantage of this plan in the case of an ammunition-hoist will be apparent when it is stated, that the entire time required on board the *Atlanta* to raise a 250-pound shell is nine and a half seconds. Now, this interval gives a man very little time to think, especially in excitement or danger; and if the ordinary arbitrary movements for starting and stopping motors were employed, an accident would, some day, result from the wrong movement being made. Furthermore, with this device, if the operator is killed, or if he lets go the handle, or if, through excitement or confusion, he ceases to pay attention to the handle, or if a shot disables the motor, or breaks its connections—in all these cases, everything stops, and the shell simply stays where it is. This is a much better thing for it to do than to violently descend, or be forced up against the deck overhead, as would happen with any other device now known.

ELECTRIC MOTORS AS AUXILIARY ENGINES IN WAR-SHIPS.

The two plans above described comprise the only uses, besides ventilating, to which electric motors have as yet been put in ships. But in the near future, it is expected

that they will largely replace the many small steam-engines with which modern war-ships are filled. The most complete and detailed statement of the scope of motors for ship use is the lecture of Mr. S. Dana Greene, formerly an Ensign in our Navy, before the Naval Institute. Mr. Greene, from his training as a naval officer and his practical experience as Chief Engineer of the Sprague Electric Motor Company, is probably more intimately acquainted with the technical features of the case than anybody else. He states that for a ship like the *Chicago*, the auxiliary engines that could advantageously be replaced by electric motors are about forty or fifty in number, and aggregate about 200 horse-power. This estimate includes only those auxiliary engines which are at some distance from the engine and boiler-rooms, and which, at present, have to be connected to the boilers by very long, crooked and expensive copper pipes. Everybody here knows that a prime necessity in a war-ship is to have the pipes that convey steam, compressed air or hydraulic power, well below the water line: and everybody knows besides that a war-ship of to-day is made up of a great many water-tight compartments; and so it will need no great amount of explanation to give them an idea of the trouble, complication and expense of leading the numberless pipes through the water-tight bulkheads and around obstructions. How much easier, cheaper and safer to run wires! A wire can be bent and twisted to any extent, provided only that its insulating covering be not broken. Steam pipes, furthermore, always contain more or less condensed steam, or water, the amount varying with the conditions of the case; and the conditions existing with the long and crooked steam pipes of a ship are such as to cause the amount of condensed steam to be very great. Now this condensation, together with the friction, causes a very great decrease of pressure of steam in the engine cylinder and a great increase of back pressure; so that the steam and vacuum gauges in the engine-room convey no idea whatever of the state of affairs at an engine 200 feet distant. In other words, there is great loss of energy between the boilers and the engines situated at a distance

from them. But with the electric motor, we can certainly count on at least eighty per cent. efficiency, or at least seventy per cent. of the horse-power of the dynamo's engine, and this engine is itself very economical and is placed near the boilers. But more than all this, the simplicity, noiselessness and cleanliness of the electric motor itself stamp it as the ideal engine for ship use, when compared with the noisy, dirty steam-engine, with its joints, and valves, and stuffing-boxes and other features requiring incessant inspection.

SEARCH LIGHTS IN SHIPS.

At the time of my previous lecture, I endeavored to show the advantages of the search light for offensive and defensive operations. This would be unnecessary now, for these advantages are admitted. At that time, the great body of naval officers in all countries were skeptical concerning it, and very many of the most able officers laughed at it as a manifest absurdity, and stigmatized its advocates as those horrible monsters—theorists. Moreover, not a few official reports were made, which damned search lights with faint praise, calling in question their effectiveness and exaggerating their limitations. But, of late, the weight of professional opinion in their favor has become enormous, and the endeavor is now simply to find out the best way to use them, under the various phases of war. Let any one take his stand on the deck of a ship at night, knowing that an attack—even a sham attack—is to be expected; let him feel for a few moments the helplessness that is born of darkness; let him strain his eyes and his ears in vain to detect the faintest glimmer or the faintest sound to betray boats which he knows are somewhere stealing to the attack—then let the search light dart out its brilliant ray, and throw out into merciless distinctness every detail of some boat 1,000 yards away—swiftly and stealthily advancing—and he will need no subtle arguments to prove to him that the search light has come to stay. Of course, one must know how to use the light and when; one must not show it when he wants to keep his position secret from the enemy; neither must he use his steam whistle. But because a

device may be used disadvantageously, is no argument against using it advantageously. And it is a fact that in all the recent naval manœuvres abroad, the search light has been employed to a great and increasing extent.

SEARCH LIGHTS IN FORTS AND ARMIES.

But it is not only in ships that we find the search light. It is used in forts, notably those defending channels, to watch for attacking vessels, and for boats attempting to countermine; and many of the continental armies have wagons which carry boiler, engine, dynamo and electric light, for use in exploring battle fields at night and in searching for the wounded and the dead.

SEARCH LIGHT IN FOG.

A novel use of the search light was made one night on board the *Atlanta*, which was caught in a suddenly descending fog in a very dangerous position in shoal water. It was not deep enough to anchor with safety, in view of the heavy sea, becoming hourly more heavy with the increasing gale; and our position on the shoals was too uncertain to warrant an attempt to get into deeper water, lest we should get into shoaler water instead. The steam-launch was lowered, and an officer in it began to sound around the ship, to find a deep channel along which it would be safe to move. But the fog was so thick that it was soon found the launch could not go far enough from the ship, for fear of being lost. At this juncture, Lieut. G. A. Calhoun made the ingenious suggestion that one of the search lamps be lighted, and its beam turned in a certain direction, and the steam launch ordered to sound along the direction of this beam as far as it could be followed. The suggestion was adopted at once. It was found that the brilliant light illumined the particles of water suspended in the air to a surprising distance along a straight and narrow line. The launch would follow the ray as far as it could, sounding as it went, then return to the ship, following the guiding ray. This ray would then be turned in a new direction, and off the launch would steam, to prosecute its investigations along this line. In a few hours, a straight and deep channel

was in this way found, and with the little launch piloting the way a short distance in advance and piping its shrill directing whistle, the big ship slowly steamed out at midnight into deep water and a safe anchorage. "This was not warfare," it may be said. No, it was not; but it gives a pithy suggestion as to how in warfare, and under certain conditions, a ship could get out of a blockaded harbor under the friendly mantle of a fog; or how a man-of-war could, under such circumstances even enter certain harbors. Of course, it would not be prudent to attempt to so enter a a harbor filled with automatic electric torpedoes; but these weapons are so elaborate and expensive, that they cannot be used everywhere, and on many coasts, the main reliance must be placed on ships, shore batteries and torpedo boats.

Not only, however, are search lights of value in enabling us to discover an approaching enemy, they also enable us to see the silhouette of the gun sights on his illuminated surface, and direct the guns with precision on the darkest night.

In cases where it is not desirable to use the search light to illumine the target, a fine wire made incandescent by a current has been used with success to make visible the sights of the gun, which, of course, cannot otherwise be seen at night. The device is so good, that one is surprised that it is so seldom used.

AUTOMATIC SEARCH LIGHTS.

In this connection it may be here stated that there is a growing feeling in naval circles in favor of a greater number of automatic search lights, even if of small power individually, in order that all parts of the vicinity may be kept visible. Torpedo boats come so quickly, that one cannot afford to let any part of the horizon remain dark while a single beam on the broadside is making the rounds.

SEARCH LIGHT WITH VERTICAL BEAM.

A curious use of the search light has been experimented with, of late, and with interesting results. The lamp is so pivoted that its ray can be projected up vertically, thus

throwing a brilliant shaft of light like a silver arrow, high into the air. It is stated that this beam can be seen in a fog further than anything else can. The theory is that a fog does not exist except close to the surface of the water, and that the beam can be seen by looking up into air not much obscured by fog; so that, in other words, one does not have to look through so much fog to see this beam high up in the air, as he would to see the ship using the beam. As yet only small search lights have been tried, but they have been sufficiently successful to warrant the similar trial of larger lights.

RANGE FINDER.

It has been mentioned above as a prime necessity of effective gunnery at sea, that the gunners shall know at each instant the exact distance of the ship at which they are to shoot. To realize this, we must reflect that, if two ships are approaching each other at the rate of even twelve knots each, their distance apart is changing at the rate of thirteen and one-third yards per second. This means that in less than four seconds, the distance, or range will change fifty yards, which represents the distance apart of two consecutive graduations on the sight-bar of a modern rifled gun. In other words, the sight-bars of high-powered guns are usually graduated to fifty yards, and it is necessary for effective shooting that an error as great as fifty yards must not be made in estimating the distance, and timing the discharge of the gun, as the ship rolls from side to side. But if this change of fifty yards is made in four seconds, we see that we must have an instrument which will give the range with less than four seconds delay, and give it at the very least with less than fifty yards error. Such an instrument is called a range finder. It may be objected that, if you close with your enemy to "point blank range," as it used to be called, or say about 500 yards, then you can fire away as fast as you please, and the flight of the projectile is so nearly horizontal, that you do not need to know the range. This is perfectly true, but it should borne in mind, that, if the enemy's ship has a range finder, he can begin at 2,000 yards at the least to deliver a careful and accurate cannonade

with heavy shell, and inflict tremendous damage on you while you are waiting for close quarters. Moreover, as soon as he discovers that you want to close, he will at once, and for that reason, try to defeat your plan and keep you at a distance, all the while pouring in his merciless fire.

Perhaps a few words of description of the newest range finder will not be out of place, especially as it has a number of features interesting from a scientific point of view. All know that every calculation of distance depends upon solving a triangle, in which a base line is known, and two angles at its ends are measured, these angles being included between the base line and lines drawn from its ends to the distant object. In surveying, theodolites are placed at the ends and the angles are read from their graduated limbs. In this range finder, a german-silver resistance wire replaces the graduated arc, while a receiving instrument, which is in fact a rheostat, sums up automatically the angles. The base line being a constant, the receiving instrument is marked in yards at once, instead of in angles. The operation of using the range finder then, is this—two observers at opposite ends of the base line, gaze continuously at the distant object using telescopes preferably. They do nothing else; but a third observer, watching a galvanometer, simply moves a contact bar along a resistance wire on the receiving instrument in such a manner as to keep a galvanometer needle always at zero. His contact bar then points at the correct distance. If the object be moving, it makes no difference; the operation is as easy as if the object were stationary, and the indications are instantaneous and continuous. With a 290-foot base line on board the U. S. S. *Chicago*, one instrument being mounted in the bow and one in the stern, the average error in the official trial was six-tenths of one per cent.; and no difficulty was found in continuously reporting the distance of moving vessels.

POSITION FINDER.

Closely related to range finding, is position finding, in which not only the distance of an object is obtained, but its exact position. It has been the practice in the forts of all

nations to divide the harbor or other adjacent water, into imaginary squares about 100 yards on a side, these squares being marked on a chart and numbered. Somewhere within or near the fort is a carefully measured base line, and at its ends, are two telescopes, or alidades, connected together by telephone, telegraph, step-by-step apparatus, or other means. At some sheltered spot is the chart above-mentioned, over which two pointers are arranged to sweep, being pivoted at the points representing the two telescopes. Now, if the observers at the telescopes keep the officer at the chart constantly advised as to how their telescopes are pointing, he simply moves his pointers to correspond, and the intersection of the pointers on the chart represents the object at which the two telescopes are directed. Noting the square upon which the pointers intersect, the officer telephones or otherwise signals to the guns to fire at square 110, 125, etc. Then the officers at the guns train and elevate their guns so as to fire into those squares, having at hand tables to direct them how to so train and elevate. It will be observed that guns can thus fire at a target when the smoke at the guns is so thick that the gunners cannot see the target. But Major Watkin, of the Royal Engineers, has improved upon this method, and very greatly. The details of his invention are guarded strictly, but some of the results are known. They are simply diabolical. Gunners who could not see a target, and did not know how far off it was or where it was, have put forty-four per cent. of hits on the deck of an imaginary iron clad at ranges of from 3,000 to 4,000 yards, or from one and three-fourths to two and one-half miles. Perhaps in the course of a few months we shall hear of a position finder invented nearer home.

All the guns of a fort can be fired with marvellous accuracy by an officer distant from the smoke, noise and confusion of the battery, but connected with observing stations so located as to command a good view of the vicinity.

FIRING GUNS BY ELECTRICITY.

A very great increase in the accuracy of gunnery at sea is secured by the plan now coming into use in all civilized

navies, by which the guns are discharged by electricity. The general idea is not new, but it is only of late that it has been made thoroughly practicable. By the old plan the gun captain ordered "right" or "left" and the sailors hauled the gun to the right or the left; or he ordered "raise" or "lower" and the sailors raised or lowered the breach of the gun. When he got the gun nearly right, the gun captain called "ready," and everybody got clear of the gun in order not to be injured by the recoil. When the motion of the ship brought the gun sights in line with the target, the gun captain pulled lustily on his lanyard, and the gun went off. But under the new system one of the sailors moves a small lever to the right or to the left, as explained above, so as to keep the gun pointed all the time in the direction of the target. The gun captain holds a small circuit-closer in his hand, and as soon as the rolling of the ship brings the sights level with the target, he simply presses his fingers, without bothering himself to see if the men are away from the gun, because the recoil will not hurt them. Knowing the exact range, and having this quiet and simple means literally at his fingers' ends, what is to prevent a gun captain from hitting the target? It must be borne in mind that the real errors in shooting at sea, are not in shooting to the right or the left of the target, but in shooting over it, or short of it. This shooting over or short arises from two things: first, having a mistaken idea of the distance; second, firing too soon or too late when the ship is rolling. Now a range finder eliminates the first error; and electric firing goes a great way towards eliminating the second error, principally because it obviates the necessity for making any allowance for delay in the firing of the gun after the gun captain has done his part. Electricity discharges a gun at the instant when the gun captain presses his fingers and not at some other time. So that if a gun captain, having his gun set at the correct range, presses his fingers when the sights are in line with the target, he will hit the target. Of course, errors of eyesight cannot thus be eliminated, neither can the errors of the gun; but both of these are both exceedingly small, so small compared with the other errors, that they are inconsiderable, as has been abundantly proved.

MARINE PROPULSION BY ELECTRICITY.

The question is often asked: "Is marine propulsion by electricity one of the probabilities of the future?" The only way to answer this query, is to decline to attempt the *rôle* of the inspired prophet, for while one would not have the hardihood to say that it will never be (remembering the solemn promise of a celebrated English scientist to *eat* the first steamer that should cross the Atlantic), yet on the other hand one would hardly dare to assert that it will be. The question is merely one of practicability; at present electric marine propulsion is not practicable, except on a small scale, but the difficulties in the way are of the nature often overcome by persistent experiment and by the improvements resulting from slow experience.

ELECTRIC LAUNCHES.

It can be definitely stated, however, that electric launches are so near a practical success that one does not need to be a prophet to discern their coming in the near future. No less an authority than Prof. Geo. Forbes declares that they are already a practical thing on the Thames for a certain class of boats, in which great speed is not essential, but in which quiet, easy motion and cleanliness are desirable. He further states that, in his boat, he has got a return of nearly sixty per cent. of the horse-power put into the storage cells in absolute power of the propeller. Some of the storage cells now in the market are quite durable, if not over-discharged or shaken up. I have a battery of thirty cells, of the size known as 7 M, which have been used in developing the range or position finder mentioned above, and they have fulfilled the purpose exactly. They were originally charged last July, and they did not have to be recharged until a month ago. They were used on board the U. S. S. *Chicago* for some months, and were subjected to a good deal of rough treatment, being moved about the decks a good deal, lowered down into a store-room and hoisted up on deck again a number of times; besides this, the sailors spit tobacco juice on them, and then played salt water on them with a hose, to wash them. The sailors

called the case containing the cells the "box of electricity." At first they looked at it with the contempt which every true man-of-war's man feels for anything scientific: but they generally acquired for it a certain respect, as time went on, and they saw what curious things the ugly black box could do.

One of the newest electric launches is *The Magnet*, 28 feet long and 6 feet beam, drawing 2½ feet of water. She carries fifty-six accumulators, weighing 2,400 pounds, or about as much as fifteen men, and these accumulators furnish the energy to drive an electric motor whose armature is on the same shaft with the propeller. It is claimed that this boat can carry twenty people in smooth water, and that she can go eighty miles at a speed of six to eight knots, or go a shorter distance at a speed of eight to ten knots. It would seem as if, even at the present stage of development, such a boat would be valuable in a war-ship, from the fact that it can be got ready for service instantly, and can go faster and longer than an ordinary man-of-war's boat, pulled by oars.

ELECTRIC PICKET BOATS.

It could do excellent work, for instance, in case of a fleet at anchor, in carrying despatches from ship to ship. The cells in the boat could be charged while the boat was lying alongside, or even when hanging at the davits; and in such emergencies as are constantly occurring in naval life, it could be lowered and started off in a few seconds; while for scout duty or lookout duty, what other boat could be so noiseless and swift?

ELECTRIC SUBMARINE BOATS.

Closely allied to electric launches are electric submarine boats, in which also the energy needed for propulsion is carried in storage cells. The newest vessel of this class, about which much is known, is the Spanish submarine torpedo boat *Peral*. Trustworthy details are hard to get, but there seems to be no doubt that she can remain under water for hours, can move at a high speed both above and below water, and that she can carry enough energy in the

storage cells to enable her to carry out any attack which a submarine boat is intended to make, *i. e.*, a sortie from a harbor upon an attacking fleet.

ELECTRIC COMMUNICATION BETWEEN SHIPS AT SEA.

I fancy that everybody here is aware of the fact that the great need of all navies is a quicker and more trustworthy means of communication between ships at sea. Doubtless, most of you know also that many experiments have been made looking to the establishment of a means of communication by electricity. Two general lines of experiment have been followed. In one, sound vibrations are set in motion in the water, and are received on a diaphragm, usually on the under water side of a ship, this diaphragm corresponding to a telephone transmitter, the receiver being in the pilot-house, or other convenient place. The other line, contemplates sending electric signals through the air or the water, the receiver being usually a telephone receiver. During about two years, a great many experiments were made at the New York Navy Yard in the latter line, signalling both through the air and through the water. These experiments were on a pretty large scale. A large dynamo was used as a source of power, and in one case the U. S. S. *Atlanta* was converted into the largest electro-magnet known, being wrapped with heavy wire, through which the dynamo current was sent, while the iron tug *Nina*, 150 feet long, was made a receiver, she being wrapped with fine wire having a telephone in circuit. But the most satisfactory results were got by sending the impulses through the water; and though nothing quite practical was reached, yet one felt all the time that it was because he was not prosecuting the experiments correctly. These experiments seem worthy of mention, because they indicate one of the few fields of electrical engineering not yet explored.

ELECTRIC SIGNALLING.

But electric signalling by lights is already a practical thing, and is used in all navies. It is not the ideal thing, and does not attempt as much as the plans above-mentioned. But it is a great improvement on the old plans,

and can do good work with skilled operators. The plan most employed is to make and break the circuit of incandescent lamps, and thus signal letters and words according to a preconcerted code. But when distant signalling is desired, between points ten miles apart, for instance, or when high land intervenes, then the penetrating ray of the search light is flashed into the sky.

In conclusion, if we compare the art of electricity in warfare at its present stage with that prevailing five years ago, and we shall see that a comparatively unimportant thing has grown to be an important thing, and that scientific apparatus is employed much more than it was then.

NECESSITY FOR EFFICIENT EQUIPMENT OF WAR-SHIPS.

Now this indicates the tendency in modern warfare; a tendency to accomplish a desirable end by any effective means, no matter how complex or how expensive. Certain objects must be attained. If a ship is to go into a fight, she must whip. A lost battle is a national regret forever. A single ship, a small one perhaps, like the *Kearsarge* may fight a battle, and of which the consequences will be altogether out of proportion to the money value of the ship. There are thousands of buildings in this country that cost more than did the little *Kearsarge;* but suppose this cheap little ship had been sunk by the *Alabama.* The thought is unendurable. Now every nation feels that each of her ships is an exponent of what she can do in that tonnage, and while no nation feels bound to build ships, each one of which can whip any ship in any other navy, she does feel bound to build and equip each ship well enough to whip any foreign ship of her size and weight. So modern ships are coming to be the foremost examples of the application of science to practical things.

TENDENCY OF MODERN WARFARE.

The sailor is still a sailor, and will always be a sailor, so will the soldier always be a soldier. The profession of arms, whether on land or sea, calls for and develops certain qualities of mind and heart. Endurance, decision and chivalric courage will win battles in the future, as in the past. The

grand principles of strategy persist, and so do the laws governing the command of men. Yet the *conditions* of warfare are changing. Simplicity is giving place to complexity. Woe to that nation which fails to note the signs of the times. War is a serious thing, but it is more serious to the vanquished than to the victor. It behooves every nation to see that by no chance shall it be vanquished. No means of offense or defense must be neglected, because it seems too delicate or too expensive, provided only that it can be made to be efficient. Science is daily coming more into our lives, as the number of those who study her increases; but in no department of life is she making more progress than in warfare; and in warfare no branch of science is making more progress than electricity.

ON SCHOOLS: WITH PARTICULAR REFERENCE TO TRADES SCHOOLS.

By Joseph M. Wilson, A.M., C.E.
President of the Franklin Institute.

[*Continued from vol. cxxx, p. 144.*]

Herr Kjennerud, after completing his description of the method of instruction adopted at Fredrickshald, goes on to say, that "it has been maintained with great force and with much justice that hand-work does not have its full rights unless it is regularly incorporated in the school course, and receives such treatment that it may exert an educating influence on the child, inasmuch as, like modelling and drawing, it aims to develop the pupil's eye, and his sense of form and of beauty." "Therefore it should have an acknowledged place, in the higher as in the lower schools." Hand-work "may certainly very easily be somewhat overrated as positively refining, and some may in a great measure, fail to look at its practical side." Hand-work, however, "can scarcely be ranked too high as a link in the true education." It is not necessary here "to consider its significance as to moral training, but if we start with the

idea, which has already been acknowledged, that schools should impart such skill to female children as every child should possess, so ought the public school to give instruction to boys in the use of the hands, so that every man, to whatever station he belongs, shall have acquired such power that he may not stand helpless in any occasion of life, in consequence of a one-sided education; then a path will have been broken by which to arrive at a method in which the school must work."

Herr Kjennerud further says that "the exercises should begin with the handling of the tools most often used in daily life, as for example the knife, axe, hammer, plane, saw, file and possibly the paint brush." "The chief importance must be attached to joiners' work for the reason that he who understands how to handle joiners' tools will have little difficulty with other simple work." "Although turning will train the eye and the sense of form and symmetry, it must still take a subordinate place, particularly where there are not the means to procure the necessary tools." "A little wood-carving can be practised, not only because it serves in a high degree to cultivate and refine the taste, but a little experience will enable one to produce tasteful pieces of work for his own recreation."

"Whittling should not be neglected, as the knife is a tool for the use of which many opportunities will be found at home."

"Whether basket-making should have a place in school is exceedingly doubtful." The material is one that will easily take any required form, the work can be made instructive, and articles for both use and ornament can be manufactured; but much practice and strong hands are needed; the work is of inferior strength and durability; the material cannot be procured in many places, and "it cannot be maintained that exercises in basket-making have a general value."

"Painting, particularly of manufactured articles of wood, appears quite suitable for work-schools." A short course in smith's work and practise in the use of the file, would be advisable, and in many cases a forge is not necessary. Tin-

plate work is less necessary, although a knowledge of soldering often comes into use and is quickly learned.

"It can hardly be allowed that shoemaking is of great importance as a means of cultivation. The position required during work is by no means the most suitable for bodily development. It is stated that the medical council of Dresden, Germany, for this reason expressed themselves against its introduction as a school branch." "Still, skill in mending shoes is so important for people of the working classes, both economically and on sanitary grounds, that its place in school may be said to be justified on this account, which cannot be said of tailoring, for which the boys have shown no liking."

"Bookbinding is hardly of practical importance, except for those schools in which there are children in whose homes there are books to bind."

"The work to be carried out should be particularly limited to actually useful objects, and such as do not lie above the pupil's power to make with little assistance. It should be customary for the pupil, as far as possible, to be self-helping, and he should not be deprived of the satisfaction and encouragement to diligence and perseverance, which are always sure to follow when one has accomplished a piece of work with only his own help." "And that there may be opportunity for the development of taste and a sense of beauty in work, when procuring models, the coarseness and ugliness which often characterizes the work of schools should be avoided."

One further extract from Herr Kjennerud's remarks will be sufficient for our present purpose. He states that "a plan derived from any other fundamental principle than that the school is for life in general, will very certainly lead astray, as has happened," in his opinion, "in some places in Sweden, where a disproportionate number of hours has been assigned to hand-work, even as many as half the whole time of instruction." "With three to six hours a week obligatory hand-work, running through two or three years, any reasonable demand would appear to be satisfied."

THE DEPARTMENT OF SCIENCE AND ART OF THE COMMITTEE OF COUNCIL ON EDUCATION, LONDON.

The Department of Science and Art was established in connection with the Board of Trade in March, 1853, as a development of the Department of Practical Art, which in 1852 had been created for the reorganization of schools of design, and it was placed under the direction of the Committee of Council on Education in 1856.

The head of the Department is the Lord President of the Council, and he is assisted by a member of the Privy Council, who is called the Vice-President of the Committee on Education, who acts under the direction of the Lord President, and for him in his absence.

A sum of money is appropriated annually by Parliament for the promotion of instruction in science and art in the United Kingdom, especially among the working classes, and it is administered by this Department. It is applied to the maintenance of the science and art museums at South Kensington, in Dublin, and in Edinburgh; of the Normal School of Science and Royal School of Mines and the National Art Training-School at South Kensington; of the Royal College of Science and the Metropolitan School of Art in Dublin, and to aid in the establishment and maintenance of local schools and classes for instruction in science and art and of local museums of science and art.

The aid is granted in the form of—

(1) Payments to the committees of schools and classes, on the results of instruction, and certificates, prizes, medals, free studentships, scholarships and exhibitions to the students.

(2) Building grants, and grants for the purchase of apparatus, examples, fittings, etc.

(3) Aid to teachers and students in attending the Normal School of Science and the National Art Training-School, South Kensington; the Royal College of Science, Dublin, and other approved centres.

(4) Loans and grants to local museums and to science and art schools.

(5) Aid to training-colleges for instruction in science and art, and to elementary schools for instruction in drawing.

The schools and classes must be those approved by the Department and they must be open at all times to the visits and inspections of its officers.

The Department is the sole judge as to grants and awards, and they may be withheld wholly or in part for any breach of the rules.

The appropriation funds depend upon the action of Parliament, and are liable to be decreased and eventually discontinued. There is, therefore, no guarantee that they will be perpetual, and it is particularly impressed upon those who benefit by them that they must not be considered as in any way establishing a claim to any payments beyond those offered from time to time. The payment of fees by students must be looked upon as essential to the maintenance of a proper system of instruction, and though at present this is not made an absolute condition of the grants, yet gratuitous instruction is only permitted exceptionally and in those places where schools or classes have but recently been established, or it can be shown to the satisfaction of the Department that the circumstances of the locality justify this relaxation of the rule.

The standard of fees must necessarily vary in different localities according to the rate of wages and other circumstances, but committees of schools should fix as high a rate as they consider can fairly be imposed and they must certify annually to the fees received. No school or class is permitted to charge abnormally low fees in order to compete with the others in the same locality. The committees of the various schools and classes are expected to fix together some minimum fee for the district.

Students of a training-college, pupils of an elementary school who pay the regular fees of that school, pupil-teachers in elementary schools, art pupil-teachers and holders of free studentships may be exempted from fees.

Every science or art school or class must be under the superintendence and management of a local committee, who engage the teachers, are generally responsible for it, and

conduct, or assist in conducting, the examinations. The committee are also responsible for all apparatus, fittings, etc., towards the purchase of which the Department has granted aid.

There are a number of rules governing the formation of a committee. It must be composed of a chairman, secretary, and at least three other members, as many persons as possible in recognized positions of public responsibility in the district being placed on the committee.

A regular series of forms and instructions are provided for guidance in establishing and maintaining schools and classes. Each school or class, as formed, is assigned a distinguishing "school number," and every year a new application form must be returned to the Department on or before October 31st, a deduction of half a crown per day being made from the next payment to the school for each day's delay in sending the return beyond that date. Annual reports must be sent in from each school or class. In certain cases the Department will permit the organization of a committee for the purpose of conducting examinations of a school or class which receives no grants.

It will be noticed that the aid granted by the Department is intended only to supplement, not supersede, local effort. The local committee is obliged to provide and maintain suitable rooms for the classes, etc., and if at any time these appear unsatisfactory or insufficient, or if there is reason to believe that the instruction or supervision is inefficient, the assistance of the Department may be reduced or withdrawn.

A grant may be made, under certain specified regulations, in aid of a new building, or for the adaptation of an existing building, for a science or art school, at a rate not exceeding 2*s.* 6*d.* per square foot of internal area, up to a maximum of £500 for any one such school.

Grants are also made for fittings, apparatus and examples, under certain regulations, to an amount not exceeding fifty per cent. of their cost, and there are special rules for endowed schools. The Department has a lien on all objects purchased with its aid, one-fifth of which determines with each

year of actual use, and after five years the objects become the property of the committee.

Teachers are required to be qualified in accordance with certain examination rules, and the class in each subject of science, or group of subjects of art, must meet under the instruction of a qualified teacher, on at least twenty-eight days during the session, each meeting being of at least an hour's duration.

Every school or class is obliged to make an annual return before October 1st of its teaching staff and time-table of instruction for the current session, and in case of an old school or class, the statistics for the past session.

The examinations are of two kinds, personal and examinations of works. The personal examination of students in science and art are held annually about May, and of training-colleges about October and December. The May examinations are open to external candidates. The examination of works commences in April, the works being sent to the Department for that purpose.

There are certain rules and regulations, which need not be detailed here, for the conduct of examinations, for arrangements for local examinations, for applications for examination papers, for the custody of such papers, to prevent the possibility of any tampering with them, and for re-examinations.

Payments are made to local committees on the results of instruction as tested by the examination of students, on condition:

(I) That the teacher is qualified under the regulations.

(II) That the teacher has given at least twenty-eight lessons during the session on the subject of science, or group of subject of arts, on which payment is claimed.

(III) That each student, on account of whom a claim is made, belongs to one or other of the following categories:

(*a*) Persons in the receipt of weekly wages, and their children if not gaining their own livelihood.

(*b*) Teachers and pupil-teachers of elementary schools in connection with the English or Scotch Education Departments, or the National Board of Education in Ireland, and their children if not gaining their own livelihood.

(*c*) Persons in the receipt of not more than £200 per annum from all sources, and their children if not gaining their own livelihood.

(*d*) Scholars in Public Elementary Schools within the meaning of the Elementary Education Acts.

(*e*) A member of a *bona fide* night class for industrial students, which meets after 6 P.M., or on Saturdays, after 2 P.M.

(IV) That each student on account of whom payment is claimed in any subject, has received twenty lessons, at least, in that subject of science—or in art in the requisite group of subjects—and that the attendances have been duly registered.

(V) That all such attendances have been made within the two years immediately preceding the examination on account of which the claim is made, and under the supervision of the same committee.

It is not deemed necessary to give here the details or amounts of the payments that are made. Medals, prizes, certificates, scholarships, etc., are awarded to students on results of examinations. There is quite a large list of these awards, which are often of very considerable value, and naturally act very effectively as incentives to study and improvement.

Grants are made to aid local efforts in founding scholarships and exhibitions, these grants, however, being only made on the condition that the scholarship or exhibition is awarded on the results of a competition, and that a sufficient sum is provided for the special purpose of the scholarship or exhibition, by the voluntary contributions of living persons.

In reference to the science and art scholarships, these must be awarded in competition among the pupils of any elementary school or schools not conducted for private profit. The object of the scholarship is to enable the committee of the local fund to maintain the successful competitor, while pursuing his studies, for one, two or three years, at a day-school approved by the Department.

The managers of the local fund must contribute £5 each year to the Department before April 5th, and this

local contribution will be supplemented by the Department with a grant of £4 for the first year; £7 for the second; and £10 for the third year. It will rest with the locality, however, to decide whether the scholarship shall be tenable for one, two, or three years. There are certain conditions governing these scholarships.

In reference to local exhibitions, the Department makes a grant of £25 per annum to the managers of the local fund, who raise by voluntary subscription, and furnish before the fifth of April the like sum for the maintenance of a student at some college or school where a thorough course of instruction in science or art of an advanced character may be obtained. His whole time must be devoted to instruction, and there are certain conditions to be observed in making the award.

Great liberality is shown in granting free admissions to museums and libraries to students, teachers and other persons of certain classes and conditions.

Grants are allowed in aid of the purchase of objects for museums in connection with schools of science and art, or established under the Public Libraries Acts, or otherwise under a municipal governing body. These grants are primarily intended to assist local museums in obtaining reproductions in plaster, or by the electrotype process, or by photography; but they are not absolutely limited to reproductions. They may be made for the purchase of original objects of art or science, but in considering applications preference is always given to those for reproductions. The objects must be approved by the Department of Science and Art; no grant will be made toward the carriage of the objects, and no object on which aid has been granted can be sold or exchanged without the permission of the Lords of the Committee of Council on Education.

Collections of objects of science and art are loaned for a short period of exhibition to schools and for an extended period to permanent museums, either at schools or established under the Public Libraries Acts or under municipal authority. Exceptional loans are also made where no schools or museums exist, provided always that the proceeds

of the exhibition are used to further or establish a school of science or art or a municipal museum.

The museums and libraries at South Kensington contain objects, books, drawings, etc., illustrative of, and apparatus for, teaching the following subjects:

Machine construction,
Building construction,
Naval architecture,
Theoretical mechanics,
Sound, light and heat,
Magnetism and electricity,
Principles of agriculture,
Chemistry,
Animal physiology,
Botany,
Navigation,
Steam,
Physiography,

and the following branches of art:

Sculpture in marble, stone, etc.
Mosaics,
Carvings in ivory, bone, etc.,
Woodwork,
Metal work,
Coins and medals,
Arms and armor,
Silversmith's work,
Jewelry,
Decorative paintings.
Enamels on metals,
Pottery and porcelain,
Glass vessels,
Stained glass,
Leatherwork, including bookbinding,
Textile fabrics,
Lace,
Musical instruments,

Apparatus, paintings, drawings, etc., are lent to schools of science and art, for purposes of study under certain conditions, these loans being of two kinds—the deposit loan, the objects being left for considerable periods; and the temporary loan, usually made for a time of twelve weeks, which under certain circumstances, may be extended.

REGULATIONS SPECIAL TO SCIENCE.

Aid is given towards instruction in the following subjects of science:

(1) Practical, plane and solid geometry.
(2) Machine construction and drawing.
(3) Building construction.
(4) Naval architecture.
(5) Mathematics.

(6) Theoretical mechanics.
(7) Applied mechanics.
(8) Sound, light and heat.*
(9) Magnetism and Electricity.*
(10) Inorganic chemistry (theoretical.)
(10p.) Inorganic chemistry (practical).
(11) Organic chemistry (theoretical).
(11p.) Organic chemistry (practical).
(12) Geology.*
(13) Mineralogy.
(14) Animal physiology.*
(15) Botany.*
(16), (17) Biology including animal and vegetable morphology and physiology.*
(18) Principles of mining.
(19) Metallurgy (theoretical).
(19p.) Metallurgy (practical).
(20) Navigation.
(21) Nautical astronomy.*
(22) Steam.
(23) Physiography.
(24) Principles of agriculture.
(25) Hygiene.

Each subject is subdivided into three stages of courses—the elementary, the advanced and honors—except mathematics, which is subdivided into seven stages, with honors in three groups of stages.

In the subjects marked with an asterisk there may be a practical as well as a written examination in honors.

The laboratory of a science school must be devoted wholly to practical work in experimental science, and if chemistry or metallurgy be taught, must be supplied with apparatus and reagents in accordance with certain regulations which need not be detailed here. The main height of the laboratory must be at least fifteen feet. If this condition is not observed, no grant towards the laboratory fittings or apparatus will be made. Apparatus grants are confined to articles of a non-destructible nature, only to those of a

permanent illustrative character, which are required by the teacher.

Instruction in experimental science must not be given without sufficient apparatus to illustrate the teaching, and lists are furnished by the Department showing the minimum amount of apparatus with which it is considered necessary that a class should be provided for teaching subjects Nos. 1, 2, 6, 7, 8, 9, 10, 10p., 11p., 12, 14, 15, 19p., 22, 23, 24. No payments will be made, on examinations held in the elementary stage, in schools which are not furnished with the required amount of apparatus, or where advanced instruction is given, without sufficient apparatus to make the experiments referred to in the syllabus of each subject. The teacher is liable to be called upon by the inspector to show his ability to use this apparatus.

Students cannot be registered for lessons in more than two subjects on any one day, or more than one lesson in any one subject—except on a Saturday, when lessons in three subjects may be registered. The lessons in practical inorganic chemistry, practical organic chemistry, and practical metallurgy, must be each of at least one hour and a half's duration.

The examinations in the three stages of a subject—or in mathematics, in a group of stages—are held at the same time, a separate series of questions being given in each stage. The elementary and advanced stages are for the general students in science classes. The honors examination is of a more advanced character. In each stage there are two grades of success—first and second class. In the second or lower class of the elementary stage, the standard of attainment required is such as will justify the examiner in reporting that the instruction has been sound, and that the students have benefited by it; but the standard may be raised from year to year.

In addition to the ordinary science examinations, examinations may be made in mathematics, navigation, nautical astronomy and steam, for the benefit of seafaring men—and for them only—three times a year in all seaport towns where local committees are formed and are willing to undertake

them. These examinations are only allowed when there are at least forty candidates, and in those subjects and stages only in which there are forty candidates in the United Kingdom.

In order that the instruction of students in science may proceed methodically, a course of instruction has been prepared for both day-schools and night classes. The number of subjects which a student can take up in one year will depend upon circumstances, especially if he only attends night classes, but it is not necessary that he should take in any one year all the subjects mentioned in that year. If special grants (as provided) are claimed, however, his studies must comprise the subjects given in the course, and in the order there stated. The student is supposed to be already familiar with the elements of arithmetic and the primary conceptions of physical science, through his studies in the elementary school.

The course of instruction is as follows:

First Year.

Mathematics. (Subject 5. First stage.)

Free Drawing. (Second grade art.)

Practical Geometry. (Subject 1.)

Chemistry, inorganic. (Subject 10. First stage.) With practical work.

Physics.—Sound, light and heat (Subject 8. First stage), or magnetism and electricity, frictional and voltaic (Subject 9. First stage), or physiography (Subject 23. First stage).

Second Year.

Elementary mechanics, including the physical properties of liquids and gases. (Subject 6. First stage.)

Physics.—Sound, light and heat (Subject 8. First stage), or magnetism and electricity, frictional and voltaic (Subject 9. First stage), or physiography (Subject 23. Second stage).

Mathematics. (Second stage, and, if possible, Fourth stage. Subject 5.)

Practical Geometry (plane and solid). (Subject 1.)

Chemistry, inorganic. (Subject 10. Second stage). With practical work.

Animal physiology (if possible). (Subject 14. First stage).

Instruction in the subjects of the second year must be kept distinct from that in those of the first year. The student should also, if possible, during the first and second years, work at mechanical drawing, as provided for in the third year.

Special application should be made in case any slight modifications in the course are desired, and they will be considered on their merits.

Third Year.

The work of this year must depend so much on the student's aptitude, and the progress he has made in the preceding course, that it is impossible to lay down the subjects for this course with any definiteness. It is essential that, before continuing his course, or commencing new subjects, he should have a sound knowledge of the first stage of mathematics, elementary mechanics, physics and chemistry; that he should have such a knowledge of practical geometry and mechanical drawing as to be able to draw and read simple plans, elevations and sections with readiness, and that he should have sufficient facility in free-hand drawing to make clear and neat explanatory diagrams.

When these subjects have been mastered, the student should, while continuing his studies in mathematics, take up the first stage of animal physiology, if he has not already done so. He will then be in a position to specialize his studies, with advantage, in one of the following groups, according to his requirements, taking up, for instance:

(1) Physics and chemistry and metallurgy.

(2) Theoretical and applied mechanics, steam and machine construction, and drawing.

(3) Theoretical and applied mechanics, and building construction and drawing.

(4) Biology.

(5) Physiography, geology, mineralogy and mining.

The student may also, with advantage, continue his free-hand drawing and practical geometry.

This course has been arranged to lay the foundation of a thorough and systematic scientific training; and while certain subjects have necessarily been omitted, yet it does not follow, on this account, that they are considered unimportant.

Thus systematic botany will be found of very great use as a preliminary to the study of natural science, and as such it may be taught in elementary schools before this course is commenced, but otherwise it cannot be considered a step in a systematic course till the student takes it up as a portion of biology in his third year.

In reference to the privileges allowed to teachers, it may be stated that arrangements are made to enable a certain number of science-teachers to attend courses of instruction in science in the Normal School at South Kensington, in the months of June, July, August and September; also, a limited number of teachers, and of students in science classes, who intend to become science-teachers, are admitted free to the sessional courses of instruction in the Normal School of Science. Science-teachers are sometimes sent abroad, and travel in the service of the Department; certain special grants, railway fares, etc., are always allowed in all these cases.

Facilities are given to science-teachers to bring their students to the Museum to examine the collections.

The Normal School of Science at South Kensington is supported by the state, and is intended to supply systematic instruction in the various branches of physical science to students of all classes. While it is primarily intended for the instruction of teachers and of students of the industrial classes, selected by competition in the examinations of the Department of Science and Art, other students are admitted, so far as there may be accommodation for them, on the payment of fees fixed at a scale sufficiently high to prevent undue competition with institutions which do not receive state aid.

The instruction is arranged in such a manner as to give a thorough training in the general principles of science, fol-

lowed by advanced instruction in one or more special branches. A "Certificate of Associateship" is granted in certain divisions or lines of study, to those who go through any one of those in the prescribed order and pass the necessary examinations. The Royal School of Mines is affiliated to the Normal School, and students entering for the "Associateship" of the School of Mines, obtain their general scientific training in the Normal School of Science. Students who are not candidates for the associateship are permitted to take up the course of instruction in one or more special branches of science, and on passing the examination they receive certificates to that effect.

The associateship of the Normal School of Science is given in one or more of the following divisions:

(I)—Mechanics,
(II)—Physics,
(III)—Chemistry,
(IV)—Biology,
(V)—Geology,
(VI)—Agriculture,

and the associateship of the Royal School of Mines in:

(VII)—Metallurgy,
(VIII)—Mining.

The session is divided into two terms, the first beginning about the 4th of October and ending about the middle of February, while the second begins with the middle of February and ends about the middle of June.

The course of instruction which lasts for three years, is the same for all the divisions for the first year, after which it is specialized in accordance with the following scheme:

First Year.

All Divisions.

First Term.	*Second Term.*
Chemistry. (Part 1.)	Physics. (Part 1.)
	Elements of Astronomy.

Mathematics and free-hand drawing throughout each term.

Second Year.

First Term.	*Second Term.*
A.—Mechanics and mechanical drawing. (Part 1.)	Elementary geology and mineralogy.
B.—Elementary biology.	

A.—For students who take associateship in Divisions I, II, III, VII or VIII.

B.—For those who take the associateship in Divisions IV, V, VI.

Instruction in mathematics so far as may be necessary, and the geometrical drawing throughout both terms.

Third Year.

I.—Mechanics

First Term.	*Second Term.*
Mechanics. (Part 2.)	Mechanics. (Part 3.)
Mathematics.	Mathematics.
Machine drawing.	Machine drawing.

II.—Physics.

Physics. (Part 2.)	Physics. (Part 3.)

III.—Chemistry.

Chemistry. (Part 2.)	Chemistry. (Part 3.)

IV.—Biology.

A.—Zoölogy. (Part 2.)	Zoölogy. (Part 2.)
B.—Botany. (Part 3.)	Botany. (Part 3.)

V.—Geology.

Geology. (Part 2.)	Geology. (Part 3.)

VI.—Agriculture.

Mechanics. (Part 1.)	Agricultural Chemistry.
Principles of Agriculture.	

VII.—Metallurgy.

Metallurgy. (Part 1.)	Metallurgy. (Part 2.)
Assaying.	Assaying.

VIII.—Mining.

First Term.	*Second Term.*
Mining.	Mining until lectures are completed.
Metallurgy.	Surveying, plan-drawing.

Three courses of evening lectures for workingmen are given during the session, in mining, astronomy and botany, the charge for admission to each course being sixpence.

[*To be continued.*]

NOTES FROM THE PARIS EXHIBITION.

Thomson's Electric Welding.—The following table gives some data regarding the power used in a number of welds and some deductions made therefrom by the writer, which may be of interest. The welds were made with wrought-iron bars; the energy was that delivered to the primary coil of the transformer; the potential was measured at the weld, and the current was calculated from the energy in the primary and the potential, allowing about 90 per cent. efficiency of the transformer.

Diameter of wrought-iron bar in inches, ...	2	2	2	1	1	¾	¾	½	½
Kilowatts in the primary, .	61·6	52·8	31·2	13	12·4	7·8	7·5	4·1	3·5
Time in seconds, ...	50	58	144	43	44	33	35	18	21
Units of heat consumed, . .	2,900	2,900	4,300	530	520	250	250	70	70
Potential at the weld in volts, ...	2.06	1·98	1·74	1·52	1·74	1·46	1·52	1·16	1·12
Current through the weld in amperes, ...	27,000	24,000	16,000	7,750	6,400	4,800	4,500	3,200	2,800

It need hardly be added that the exhibit of the Thomson welding machinery in operation, attracted probably more attention among both technical persons and the general public than any other electrical exhibit. This process represented one of the very few recent developments in electricity, of an important character in an entirely new direction.

The Bernados process of welding by the electric arc was also exhibited in operation, but it was not a success. It burns the metal, is slow, and presents very few advantages, if any, over the usual blacksmith's process. They used accumulators of 75 volts, and a current of 200 ampères. Its only commercial application at present is for welding nickel tubes on to wrought-iron ones for use in glass-blowing.

CARL HERING.

APPENDIX

TO REPORT OF SUB-COMMITTEE NO. 1,554: COMPRISING THE RECORD OF THE TESTS OF THE BATES SPINDLE, MADE BY MR. SAMUEL WEBBER.

PHILADELPHIA, March 16, 1890.

Messrs. Leclere, Fowler, Cheney, LeVan, Lees, Bilgram, Hall and Wiegand, Committee FRANKLIN INSTITUTE.

GENTLEMEN: I have carefully attended to the duty to which you have assigned me, to test the "Bates spindle" and beg leave to submit the following report: I must first premise that the spindles are too new to be fairly tested having run only about three months, while my experience has taught me that it takes at least six months to wear a spindle, as it usually leaves the shop, to its proper bearings. In proof of this I would refer you to the tests of a Bridesburg frame of Excelsior spindles at the Stark Mills in Manchester, N. H., in 1875, as follows:

The frame of 204 spindles then about three months old, the spindle weighing about eight and one-half ounces, at 4,785 revolutions per minute with a two-inch ring, required in August 7·38 foot-pounds per spindle, or at the rate of seventy-four and one-half spindles per horse-power.

The same frame repeated in November at 4,930 revolutions per minute took 6·54 foot-pounds per spindle, or eighty-four spindles per horse-power. The record of these tests will be found on pp. 70 and 71 of the *Manual of Power*, published by me in 1879, as well as other notes showing the difference due to the tension of the bands.

In the first frame tested of the Bates spindle, at Cal-

laghan's mills, at Angora, on Thursday, March 13, 1890, this tightness of fit was very evident, as several of the spindles heated sufficiently in their bearings to warm the bolster rail perceptibly, while the Whitin spindle, which had been running some three years, ran perfectly cool, both on No. 30 yarn. I will, however, report the test, as follows, with two frames of 204 spindles each:

	Bates Sp.	*Whitin Sp.*
Revolutions of front roll, counted,	100	100
Revolutions of spindles, calculated,	8,360	8,160
Average power in foot-pounds per spindle,	8·11	5·50
Average number spindles per horse-power,	67·4	100
Average horse-power per frame,	3·144	2·219

The tests were made with both full and empty bobbins and averaged, but the total difference between full and empty bobins was only 129·5 foot-pounds for the frame of Bates spindles, while it was 180 foot-pounds with the frame of Whitin spindles, showing steadier motion for the former. The test of the Whitin spindle almost precisely duplicated similar tests at the mills at Manchaug, Mass., in September, 1887, at nearly the same velocity on nearly the same number of yarn, and in both cases the frames were in the best running order. On Monday, March 17th, a similar set of tests was made at the Gloucester Gingham Mills, Gloucester, N. J., the comparison being made between the Bates spindle and the Excelsior spindle, both built by the Bridesburg Manufacturing Company. Here, as before, the Bates spindle had been running only about three months, while the Excelsior had been running since July, 1881.

These frames were both running on No. 26 yarn, and the tests show as follows:

	Bates Sp.	*Excelsior.*
Revolutions of front roll, counted,	102	107
Revolutions of spindle, calculated,	8,039	8,430
Foot-pounds per spindle, bobbins ½ full,	7·35	6·89
Spindles per horse-power, bobbins ½ full,	75	80
Horse-power per frame, bobbins ½ full,	2·727	2·554
Rolls disconnected, H. P. for rolls only,	·462	·491
Rolls disconnected, spindles and cylinder,	2·264	2·064
Rolls disconnected, cylinder only,	·462	·462
Rolls disconnected, spindles only,	1·802	1·70
Spindles per horse-power, spindles only,	113	120

I have no tests of the Excelsior spindle on the same number of yarn and at the same speed, for comparison, but so far as I can compare them I see no great variation from those I have previously made.

Referring to what I have previously said, I see no reason to doubt that, after three or four months' operation, the Bates spindle will run with as little power as the Excelsior, and perhaps with the Whitin, which is so far the lightest spindle I have ever tested.

One or two slight mechanical changes, which Mr. Bates has in mind—such as reducing superfluous bearing surfaces, etc.—will, I think, accomplish this end without detracting from the simplicity and accessibility of this spindle, which I consider its great merits.

Respectfully submitted,

SAMUEL WEBBER.

P. S.—I find, in looking over the above, that I have omitted another very important point, viz: that the pulleys on both frames with the Bates spindle were so small (being only seven and eight inches diameter, respectively), that a tighter belt was required to drive the frames up to speed than was necessary for the frame with the Whitin and Excelsior spindles (both of which had ten-inch pulleys), and this very difference would easily make five per cent. addition to the power consumed. S. WEBBER.

NOTES ON THE STRENGTH OF GEAR TEETH.

CHARLESTOWN, N. H., April 9, 1890.

ED. JOURNAL FRANKLIN INSTITUTE:

Dear Sir: I had occasion, recently, to make some calculations as to the size of some gears required to transmit 600 horse-power at a velocity of gear surface of about 2,000 feet per minute, and in so doing referred to a paper contributed by Mr. John H. Cooper, now of the Southwark Foundry and Machine Company, to the JOURNAL OF THE FRANKLIN INSTITUTE, in July, 1879.

I was at first struck with the great discrepancy in the

results obtained from the different formulæ quoted by Mr. Cooper, and which I will not take up space by repeating; but after careful study of the mass of data which he has condensed with great labor, I began to see daylight and to get a clear view of what I was in search of. To begin with, the great mass of the English rules are old, and are evidently calculated on the supposition that the whole strain must be resisted by one corner of one tooth. The rules of Haswell, and Jones and Laughlin are calculated for a fair bearing of the face of the tooth, and the latest rules of Nystrom, which give just double the power of that of Jones and Laughlin, are based on the full contact of two teeth, which may be relied on in gears of over thirty-six teeth, as the necessary intersection of the two circumferences will cover an arc of about 20°.

To settle the matter in my own mind, I went back to Boulton and Watt's statement, quoted by Mr. Cooper as follows:

"A bar of cast iron one inch square and twelve inches long, bears 600 pounds before it breaks; one inch long will bear 7,200 pounds, and $\frac{1}{15}$ of this 480 pounds, which is the load that should be put on a wheel."

Mr. Cooper says: "We can, therefore, rely upon Boulton and Watt's data—*i.e.*, 7,200 pounds breaks a bar of cast iron one inch square by one inch long; $\frac{12\,00}{3}$ = 2,400 pounds, the elastic limit, which if exceeded would end in rupture, and $\frac{24\,00}{5}$ = 480 = the safe load."

Now, these results are based on the strength of English iron. American iron is stronger, not only as shown in Mr. Cooper's data, but in the following tests, which I quote from results published in the *American Machinist*, October 3, 1889, by Mr. Thomas B. West, from tests made by Rogers, Meacham and Shields, of Cincinnati, and which I have reduced to the same basis of one inch square:

Mr. Cooper's Data.	*Mr. West's Data.*
pounds.	*pounds.*
7,200	11,536
7,590	5,040
6,012	9,180

Mr. Cooper's Data. pounds.	*Mr. West's Data.* pounds.
7,416	6,720
6,720	7,278
8,000	7,824
6,000	8,754
11,046	7,470
6,207	7,974
7,969	8,478
	9,684
10) 74,166	11) 89,944
7,416·6 = average.	8,177 = average.

I, therefore, think it safe to assume 7,500 pounds, instead of 7,200, as the breaking strain, and $\frac{1}{15}$ of that, or 500 pounds, instead of 480, as the safe load. Being a decimal, it is easier to calculate. If American iron will stand 8,000 pounds, the factor will be 16 to 1. This Nystrom assumes, and formulates accordingly.

Now, if we take 500 as this coefficient, and apply it to the old rule, $\frac{f\,t^2}{l}$ = we have $500\,\frac{f\,t^2}{l}$ as the safe load.

Apply this to a tooth two inches thick. By Prof. Willis' rule of pitch = 2·2 t, and face = 2·5 P, we have pitch 4·348 inches, and face 10·87 inches. If the length of tooth to pitch line be $\frac{4}{10}\,P$, it will be 1·74 inches, and if whole length be $\frac{7}{10}\,P$, it will be 3·04 inches.

Then $S = 500\,\frac{f\,t^2}{l}$ gives 10,870 pounds safe load at pitch line, and $\frac{f\,t^2}{l}$ gives 7,135 pounds safe load at tip. The average would be 9,814 pounds. If we discard the t^2 and the l, and say instead $a = 500\,f\,t$, we get 10,870 pounds, a little over the average, but compensated by the fact that the strain is never wholly on the tip of one tooth long. Now, we make $F = 5{\cdot}50\,T$, and "$F\,T$" will be $= 5{\cdot}50\,t^2$. A horse-power is 550 pounds lifted one foot in a second, or v.

Then $\frac{500 \times 5{\cdot}50\,T^2}{550} = (5\,v\,t^2) = 1$ horse-power, which is nearly the same as Haswell's formula of $5{\cdot}45\,v\,t^2$, but a little stronger.

GEAR TABLE HP. $= 5 \overset{'11}{vt^2}$ PER FRACTIONS OF AN INCH. FACE = PITCH × 2½".

Pitch.	Thickness of Tooth.	Velocity in Feet per Minute.																	
		20	30	40	50	60	70	80	90	100	200	300	400	500	600	700	800	900	1,000	1,100
		HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.
¼	·114	·0217	·0324	·0434	·054	·0651	·0756	·0863	·0972	·108	·217	·324	·434	·54	·651	·756	·868	·972	1·085	1·193
⅜	·170	·0482	·0723	·0964	·1205	·1446	·1687	·1928	·2169	·241	·482	·723	·964	1·205	1·446	1·687	1·928	2·17	2·41	2·651
½	·227	·0858	·1287	·1716	·2145	·2574	·3·0	·3432	·3861	·429	·858	1·287	1·716	2·145	2·574	3·	3·432	3·86	4·29	4·72
⅝	·284	·1343	·1863	·2686	·3105	·4019	·4347	·5372	·559	·621	1·343	1·863	2·686	3·105	4·03	4·347	5·372	5·59	6·21	6·83
¾	·341	·193	·2895	·396	·4285	·579	·6755	·772	·8485	·965	1·93	2·895	3·96	4·825	5·79	6·755	7·72	8·485	9·65	10·61
⅞	·398	·264	·3954	·527	·659	·791	·9226	1·054	1·186	1·318	2·636	3·954	5·27	6·59	7·90	9·205	10·54	11·86	13·18	14·50

Pitch.	Thickness of Tooth.	Velocity in Feet per Minute.																	
		1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	2,600	2,700	2,800	2,900	3,000
		HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.
¼	·114	1·301	1·41	1·52	1·63	1·745	1·854	1·96	2·07	2·17	2·28	2·38	2·49	2·60	2·71	2·82	2·92	3·03	3·14	3·25
⅜	·170	2·89	3·13	3·37	3·61	3·85	4·09	4·33	4·57	4·82	5·05	5·29	5·53	5·77	6·01	6·25	6·59	6·83	7·07	7·32
½	·227	5·15	5·58	6·	6·43	6·86	7·29	7·72	8·14	8·58	9·44	9·87	10·29	10·725	11·15	11·58	12·01	12·44	12·87	13·30
⅝	·284	7·45	8·07	8·69	9·31	9·93	10·55	11·17	11·79	13·43	14·05	14·67	15·29	15·91	16·53	17·15	17·77	18·39	19·	19·64
¾	·341	11·58	12·54	13·5	14·465	15·43	16·39	17·36	18·32	19·30	20·26	21·23	22·19	23·16	24·12	25·09	26·05	27·	28·	28·95
⅞	·398	15·82	17·14	18·46	19·78	21·10	22·41	23·73	25·05	26·36	27·68	29·	30·3	31·63	32·95	34·27	35·58	36·9	38·22	39·54

TABLE No. 2.—*Safe stress in ft. lbs. (on Pitch line) from Mr. Christie's* ($F \times P \times 3{,}700$) *altered to Ratio of* ($F \times P^2 \times 3{,}700$). *Calculated for* P^2 *only. Multiply by ratio of F to P.* 2, 2·5, *or* 3 *to* 1.

		Breaking Strain.		Factor of Safety 4 to 1 for Quiescent Loads, or Hand-Gears, with Careful Usage		Factor 6 to 1 for Hand-Gears with Rough Usage.		Factor 8 to 1 for Steam-Power Steadily Applied.		Factor 10 to 1 for Steam-Power Liable to Sudden Reversion.	
Pitch.	Thickness.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
¼"	·114	231	344	58	86	39	57	29	43	23	34
⅜	·170	520	773	130	193	87	129	65	96	52	77
½	·227	925	1,375	231	344	154	229	116	172	92	137
⅝	·284	1,445	2,035	361	509	221	339	180	254	144	203
¾	·341	2,081	3,093	520	773	347	515	260	385	201	309
⅞	·398	2,833	4,211	708	1,053	472	702	354	526	283	421
1	·454	3,700	5,500	925	1,375	617	917	472	687	370	550
1¼	·568	5,781	8,580	1,445	2,145	963	1,430	722	1,072	578	858
1½	·682	8,325	12,375	2,081	3,093	1,387	2,063	1,040	1,546	832	1,237
1¾	·795	11,331	16,830	2,833	4,207	1,888	2,605	1,416	2,103	1,133	1,683
2	·909	14,800	22,000	3,700	5,500	2,467	3,667	1,850	2,750	1,480	2,200
2¼	1·023	18,731	27,844	4,683	6,961	3,122	4,660	2,341	3,480	1,873	2,784
2½	1·136	23,125	34,375	5,781	8,580	3,854	5,729	2,890	4,290	2,312	3,437
2¾	1·25	27,981	41,594	6,995	10,398	4,663	6,932	3,497	5,199	2,798	4,159
3	1·363	33,300	49,500	8,325	12,375	5,550	8,250	4,162	6,187	3,330	4,950
3¼	1·477	39,081	58,280	9,770	14,570	6,513	9,713	4,885	7,285	3,908	5,828
3½	1·591	45,325	67,375	11,331	16,830	7,554	11,229	5,665	8,415	4,532	6,737
3¾	1·704	52,031	77,343	13,008	19,336	8,672	12,890	6,504	9,668	5,203	7,734
4	1·818	59,200	88,000	14,800	22,000	9,867	14,667	7,400	11,000	5,920	8,800
4¼	1·932	66,830	99,330	16,708	24,842	11,138	16,555	8,354	12,420	6,683	9,933
4½	2·045	74,925	111,375	18,731	27,844	12,487	18,562	9,365	13,922	7,492	11,137
4¾	2·158	83,480	124,080	20,870	31,020	13,913	20,680	10,435	15,510	8,348	12,409
5	2·272	92,500	137,500	23,125	34,375	15,416	22,916	11,562	17,197	9,250	13,750
5¼	2·386	101,980	151,580	25,495	37,895	16,996	25,263	12,747	18,947	10,198	15,158
5½	2·500	111,923	166,375	27,981	41,594	18,654	27,730	13,990	20,791	11,192	16,637
5¾	2·613	122,331	181,830	30,583	45,457	20,388	30,305	15,291	22,728	12,233	18,183
6	2·727	133,200	198,000	33,300	49,500	22,200	33,000	16,650	24,750	13,320	19,800

It would give, applied to Mr. Cooper's second table, 149·226 horse-power for one tooth, as against Jones' and Laughlin's, 147·27 horse-power, and 298·45 horse-power for two teeth, as against Nystrom's 295·59 horse-power. The only difference being that, instead of following Mr. Cooper exactly, I have unthinkingly switched off onto the rule of my old friend, Prof. Willis, and given t as ·4545 P, instead of ·46 P, as Mr. Cooper has it. It is sufficient to show me that the formulæ of both Jones and Laughlin and Nystrom are reliable, *provided*, which is the great point, that the gears are rigidly supported in their bearings, and kept square up to the work on their full faces, and the shafts fully up to Mr. Francis' rule of

$$\text{Diam.} = \sqrt[3]{\frac{\text{H.P.} \times 100}{\text{Rev. per min.}}}$$

I also send you a gear table, which I have calculated on the above basis, which may be convenient to some of your readers; acknowledging my obligations to Mr. Cooper for the valuable collection of *data* which he has got together.

Yours very truly,

SAMUEL WEBBER.

By the suggestion of Mr. Cooper, I have also prepared a table, showing the breaking and safe strains, on teeth of different sizes, taking as a basis Mr. Christie's formula of ($P \times F \times 3{,}700$).

This I change to ($P^2 \times$ Ratio of $F \times 3{,}700$), which is the same thing really, for convenience in determining the relative values of P and F, and in order that the rule may be applicable to teeth of different width of face, and it only differs in this case from Mr. Cooper's result from Mr. Christie's formula as 10,405 pounds to 10,395 pounds.

P is here taken at the *pitch line*, but, by careful examination, I think it may be assumed that the thickness of a well-formed tooth at the base will be about 1·4 times that at the pitch line, giving a square of 1·96 to 1, while the leverage from the extreme tip would be as 1·75 to 1 at pitch line.

FACE OF TOOTH = PITCH × 2½.

Table of reliable Horse-Power, from Gears, of different pitch, at different Velocities, from Formula (HP. $= 5\,\frac{11}{VT^2}$) *giving a factor of safety of* 15 *to* 1 *on one tooth. These Formulæ are for Cast Iron*
36 teeth will give twice the power when 2 teeth are in full bearing at the same time and the same with steel. Factor of Safety will be 10 *to* 1, *with Gears of* 10 *to* 15 *teeth,*

Pitch.	Thickness.	20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	200 ft.	300 ft.	400 ft.	500 ft.	600 ft.	700 ft.	800 ft.	900 ft.*	1,000 ft.	1,100 ft.	1,200 ft.	1,300 ft.	1,400 ft.	1,500
		HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.
1″	·4545	·345	·517	·689	·862	1·03	1·21	1·38	1·55	1·724	3·448	5·17	6·89	8·62	10·34	12·07	13·79	15·51	17·24	18·96	20·69	22·41	24·13	25·
1¼	·568	·538	·806	1·07	1·34	1·61	1·88	2·15	2·42	2·688	5·377	8·06	10·75	13·44	16·13	18·82	21·50	24·19	26·88	29·57	32·26	34·94	37·63	40·
1½	·682	·775	1·16	1·55	1·94	2·32	2·71	3·10	3·49	3·875	7·75	11·62	15·50	19·37	23·25	27·12	31·	34·87	38·75	42·62	46·50	50·37	54·25	58·
1¾	·795	1·053	1·58	2·11	2·63	3·16	3·68	4.21	4·74	5·265	10·53	15·79	21·06	26·32	31·59	36·85	42·12	47·38	52·65	57·91	63·18	68·44	73·71	78·
2	·909	1·39	2·09	2·78	3·48	4·18	4·87	5·57	6·27	6·965	13·93	20·89	27·86	34·82	41·79	48·75	55·72	62·68	69·65	76·61	83·58	90·54	97·51	104·
2¼	1·023	1·74	2·61	3·48	4·36	5·23	6·10	6·97	7·84	8·715	17·43	26·14	34·86	43·57	52·29	61·	69·72	78·43	87·15	95·86	104·58	113·3	122·	130·
2½	1·136	2·15	3·22	4·30	5·37	6·45	7·52	8·60	9·67	10·75	21·50	32·25	43·	53·75	64·56	75·25	86·	96·75	107·5	118·25	129·	139·75	150·5	161·
2¾	1·25	2·60	3·90	5·21	6·51	7·81	9·11	10·42	11·72	13·02	26·05	39·06	52·08	65·10	78·12	91·14	104·16	117·18	130·20	143·22	156·24	169·26	182·28	195·
3	1·363	3·10	4·64	6·19	7·74	9·29	10·84	12·38	13·93	15·48	30·96	46·44	61·92	77·4	92·88	108·36	123·8	139·32	154·8	170·28	185·76	201·24	216·72	232·
3¼	1·477	3·63	5·45	7·27	9·09	10 9	12·72	14·54	16·36	18·17	36·35	54·52	72·7	90·87	109·05	127·2	145·4	163·6	181·75	199·92	218·10	236·27	254·4	272·
3½	1·591	4·22	6·33	8·44	10·54	12·65	14·70	16·87	18·98	21·09	42·18	63·27	84·36	105·45	126·55	147·6	168·7	189·8	210·9	232·	253·1	274·2	295·3	316·
3¾	1·704	4·84	7·26	9·68	12·1	14·52	16·94	19·36	21·78	24·2	48·4	72·6	96·8	121·	145·2	169·4	193·6	217·8	242·	266·2	290·4	314·6	338·8	363·
4	1·818	5·51	8·26	11·01	13·77	16·52	19·28	22·03	24·79	27·54	55·08	82·6	110·14	137·7	165·25	192·8	220·3	247·9	275·4	302·9	330·5	358·	385·6	413·
4¼	1·932	6·21	9·33	12·44	15·55	18·66	21·77	24·88	28·	31·10	62·2	93·3	124·4	155·5	186·6	217·7	248·8	279·9	311·1	342·2	373·3	404·4	435·5	466·
4½	2·045	6·97	10·45	13·94	17·42	20·9	24·4	27·9	31·36	34·85	69·7	104·5	139·4	174·2	209·1	244·	278·8	313·6	348·5	383·3	418·2	453·	487·9	522·
4¾″	2·158	7·76	11·64	15·52	19·4	23·28	27·10	31·05	34·93	38·81	77·62	116·4	155·2	194·	232 8	271·6	310 5	349·3	398·1	426·9	465·7	504·5	543·3	582·
5	2·272	8·60	12·9	17·2	21·5	25·8	30·1	34·4	38·7	43·01	86·03	129·	172·	215·	253·	301·	344·	387·	430·	473·	516·	559·	602·	645·
5¼	2·386	9·49	14·23	19·	23·7	28·5	33·2	38·	42·7	47·44	94·88	142·3	189·8	237·2	284·6	332·1	379·5	427·	474·	521·8	569·3	616·7	664·2	711·
5½	2·50	10·42	15·62	20·83	26·	31·2	36·4	41·7	46·9	52·08	104·2	156·2	208·3	260·4	312·4	364·5	416·6	463·7	520·8	572·9	624·9	677·	729·	781·
5¾	2·613	11·38	17·07	22·76	28·45	34·14	39·83	45·5	51·2	56·9	113·8	170·7	227·6	284·5	341·4	398·3	455·2	512·1	569·	625·9	682·8	739·7	796·6	853·
6	2·727	12·39	18·59	24·8	31·	37·	43·4	49·6	55·8	61·97	123·9	185·9	248·	310·	372·	434·	496·	558·	620·	682·	744·	806·	868·	930·

* Velocity in feet per min. at pitch line.

FACE OF TOOTH = PITCH × 2½.

(HP. = $5\sqrt[11]{VT^2}$) *giving a factor of safety of* 15 *to* 1 *on one tooth. These Formulæ are for Cast Iron. Cast Steel wi*
e same time and the same with steel. Factor of Safety will be 10 *to* 1, *with Gears of* 10 *to* 15 *teeth, where one tip clear*

400 ft.	500 ft.	600 ft.	700 ft.	800 ft.	900 ft.*	1,000 ft.	1,100 ft.	1,200 ft.	1,300 ft.	1,400 ft.	1,500 ft.	1,600 ft.	1,700
HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.
6·89	8·62	10·34	12·07	13·79	15·51	17·24	18·96	20·69	22·41	24·13	25·86	27·58	29·
10·75	13·44	16·13	18·82	21·50	24·19	26·88	29·57	32·26	34·94	37·63	40·32	43·	45·
15·50	19·37	23·25	27·12	31·	34·87	38·75	42·62	46·50	50·37	54·25	58·12	62·	65·
21·06	26·32	31·59	36·85	42·12	47·38	52·65	57·91	63·18	68·44	73·71	78·97	84·24	89·
27·86	34·82	41·79	48·75	55·72	62·68	69·65	76·61	83·58	90·54	97·51	104·47	111·44	118·
34·86	43·57	52·29	61·	69·72	78·43	87·15	95·86	104·58	113·3	122·	130·72	139·44	148·
43·	53·75	64·56	75·25	86·	96·75	107·5	118·25	129·	139·75	150·5	161·25	172·	182·
52·08	65·10	78·12	91·14	104·16	117·18	130·20	143·22	156·24	169·26	182·28	195·3	208·32	221·
61·92	77·4	92·88	108·36	123·8	139·32	154·8	170·28	185·76	201·24	216·72	232·2	247·7	263·
72·7	90·87	109·05	127·2	145·4	163·6	181·75	199·92	218·10	236·27	254·4	272·6	290·8	308·
84·36	105·45	126·55	147·6	168·7	189·8	210·9	232·	253·1	274·2	295·3	316·4	337·5	358·
96·8	121·	145·2	169·4	193·6	217·8	242·	266·2	290·4	314·6	338·8	363·	387·2	411·
110·14	137·7	165·25	192·8	220·3	247·9	275·4	302·9	330·5	358·	385·6	413·1	440·6	468·
124·4	155·5	186·6	217·7	248·8	279·9	311·1	342·2	373·3	404·4	435·5	466·6	497·7	528·
139·4	174·2	209·1	244·	278·8	313·6	348·5	383·3	418·2	453·	487·9	522·7	557·6	592·
155·2	194·	232 8	271·6	310 5	349·3	388·1	426·9	465·7	504·5	543·3	582·1	620·9	659·
172·	215·	253·	301·	344·	387·	430·	473·	516·	559·	602·	645·	688·	731·
189·8	237·2	284·6	332·1	379·5	427·	474·	521·8	569·3	616·7	664·2	711·6	759·	806·
208·3	260·4	312·4	364·5	416·6	468·7	520·8	572·9	624·9	677·	729·	781·	833·2	885·
227·6	284·5	341·4	398·3	455·2	512·1	569·	625·9	682·8	739·7	796·6	853·5	910·4	967·
248·	310·	372·	434·	496·	558·	620·	682·	744·	806·	868·	930·	992·	1054·

. Cast Steel will give one-half more power. Cast Iron Gears of over ere one tip clears as another takes hold.

1,600 ft.	1,700 ft.	1,800 ft.	1,900 ft.	2,000 ft.	2,100 ft.	2,200 ft.	2,300 ft.	2,400 ft.
HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.	HP.
27·58	29·31	31·03	32·75	34·48	36·20	37·93	39·65	41·37
43·	45·70	48·38	51·07	53·77	56·46	59·15	61·83	64·52
62·	65·87	69·75	73·62	77·50	81·37	85·25	89·12	93·
84·24	89·50	94·77	100·	105·3	110·56	115·83	121·09	126·36
111·44	118·4	125·37	132·33	139·30	146·26	153·23	160·19	167·16
139·44	148·15	156·87	165·58	174·3	183·	191·73	200·44	209·16
172·	182·75	193·5	204·25	215·	225·75	236·5	247·25	258·
208·32	221·34	234·36	247·4	260·5	273·52	286·54	299·56	312·58
247·7	263·16	278·64	294·12	309·6	325·08	340·56	356·04	371·52
290·8	308·9	327·1	345·3	363·5	381·7	399·8	418·	436·2
337·5	358·6	379·6	400·7	421·8	442·9	464·	485·1	506·2
387·2	411·4	435·6	459·8	484·	508·2	532·4	556·6	580·8
440·6	468·2	495·7	523·3	550·8	578·3	605·9	633·4	661·
497·7	528·8	559·9	590·	621·1	653·2	684·3	715·4	746·5
557·6	592·4	627·3	662·1	697·	731·8	766·7	801·5	836·4
620·9	659·7	698·5	737·3	776·2	815·	853·8	892·6	931·4
688·	731·	774·	817·	860·	903·	946·	989·	1032·
759·	806·4	853·9	901·3	949·	996·3	1043·7	1091·2	1138·6
823·2	885·3	937·4	989·5	1042·	1094·	1146·	1198·	1250·
910·4	967·3	1024·2	1081·1	1138·	1195·	1252·	1309·	1366·
992·	1054·	1116·	1178·	1240·	1302·	1364·	1426·	1488

This practically eliminates *l*, and the fact that the tips of the teeth are so rounded off that the pressure seldom comes on the extreme point of one tooth, and when it does, is diagonal to the line of least resistance, instead of vertical, enables me to do so entirely, and, as my table, made out in this manner, gives for a safe strain for a tooth of three-inch pitch, such as Mr. Cooper uses for his basis, with a factor of 8 to 1, a load of 4,162 pounds × 2·5, or 10,405 pounds, while Mr. Nystrom, with the same factor, gives, by formula 20, 10,350 pounds, and by formula 21, 12·242 pounds, I think it is safe. S. W.

NOTE ON FRESH-WATER WELLS OF THE ATLANTIC BEACH.

Anything which will throw light upon the character of the drinking water which is supplied to the hundreds of thousands of sojourners by the New Jersey sea-coast, must necessarily have interest to the public, and especially to parents, for nowhere else does a sick child recover so rapidly as at the seashore, if other conditions are favorable.

The practice, during the last five years, has tended toward sinking artesian wells near most of the larger summer hotels. The supply of water by this means was so abundant and excellent that the New Jersey State Geological Survey, under the late able and much lamented Prof. George Cook, determined the water-bearing planes, and published the depths at which these might be expected in bore holes along the sea-coast from Sandy Hook to Cape May. The wells which have since been driven have amply proved the soundness of the data.

But in numbers of cases it is not possible to resort to deep boring, and in these cases the supply is by surface wells sunk a short distance below the sand. Of course, these wells are permissible only in cases where, for a considerable distance around them, the population is sparse and there are few cesspools or collections of decaying matter, and in some cases these conditions obtain sufficiently to justify the

use of surface wells, but sooner or later these must be abandoned and recourse must be had to artesian borings, which, fortunately, need not be very deep, to furnish an ample supply for all needs.

In order to give to the layman an idea of the condition of the strata and their relation to the water supply of the coast, it may be said that the famous marl beds of New Jersey, with the clays and sands which divide and intermingle with them, form impervious beds through which water cannot percolate. They cross the State from about Long Branch to the old town of Salem, near Fort Delaware, running approximately southwest, and inclining or dipping in a direction perpendicular to this (or southeast), at a gentle angle of about twenty feet to the mile. These are the water-bearing floors which supply the greater part of the artesian wells sunk along the coast between Long Branch and Cape May, though there are other and higher planes along which more or less good water is constantly flowing downward to and entering the sea at a greater or less distance from the coast. The permanence and purity of a supply will depend upon the extent of country which pours its rainfall upon the upper edges of these marl strata or the overlying clay beds. The outcrop of these strata is not parallel with the coast line, but runs inland to the southwest; it is, therefore, obvious that the farther one goes to the south from the intersection of these strata with the ocean border, the deeper must the well be bored in order to find water. One of the upper marl beds touches the sea line at Asbury Park, and the next higher marl at about Branchport. To reach the water flowing along the upper planes of the first deposit at the Beach House, Sea Girt, for instance, one would be obliged to sink about 160 feet; and to reach the probably larger supply of the marl next below at the same point, a depth of 240 feet would be required. But before coming upon these well-known horizons of good water, it is extremely probable that others would be found, representing higher clays, as was the case at Berkeley, on the Barnegat Beach.

But to return to the surface wells. There is at the

Beach House a well sunk by Commodore Stockton, when the middle house was his seaside home. This well is familiar to all who have visited this place. It is a prominent object on the lower porch of the hotel, and furnishes all the water consumed for drinking and cooking purposes. The depth of the bottom of the well is 20 feet 5 inches from the surface, and its average depth of water is three feet. One of its peculiarities which astonishes those unfamiliar with the behavior of streams of water at points near their confluence with another body of water of varying depth, is that the level of the perfectly sweet and fresh water rises and falls with the tide in the ocean 150 feet to the east of it. This is not at all remarkable when one reflects that the same ocean tide causes the fresh water of the Delaware and Schuylkill to rise, and their surface currents to retreat towards the mouths of those streams, though eighty-odd miles from the ocean.

The water which fills this well represents the drainage of a few square miles around Sea Girt, and is simply the rain water filtered through the sand and gravel of the coast belt, and collected on the surface of some local intercalated bed of clay. Were the region thus drained as thickly populated as a few other parts of the coastal belt the water would probably be unfit for drinking purposes; but it happens that the settlement of this area is sparse and its contamination from putrifying substances small. The writer has been in the habit of drinking the water of the Stockton well for eleven summers, and of seeing it continually used by invalids and children without ever having heard of any deleterious effect produced by it.

For the purpose of investigating whether or not it were potable as well as to learn something of the nature of the water from similar wells on the New Jersey coast, having first filled and rinsed a perfectly clean five-gallon demijohn twelve times with water, he collected a fair average sample. Subjoined are the results of this examination:

Water slightly alkaline:	*In a Million Parts.*	*Grains per Gallon.*
Free ammonia,	0·033	—
Albuminoid ammonia,	0·090	—
Chlorine,	—	4·2
Total solids in solution,	—	29·0

As to the two forms of ammonia this corresponds closely with an analysis by Wanklyn, of the water of the River Lea, supplied by the East London Water Company to the citizens of London. The percentage of albuminoid ammonia is only 0·01 higher than that found by the same distinguished analyst in the water of Loch Katrine, which supplies the people of Glasgow. While not extraordinary on account of its purity it is well within the limits beyond which chemical analysis indicates danger.

The same is the case with the chlorine and total solid constituents. They present no ground for suspicion of dangerous contamination, and indicate what a subsequent examination of the drainage system proved, viz: that the latter was in good condition, and carried all sewage in closed pipes to an inlet connecting with the Manasquan River about a mile away from the house. This is but one instance, and it may be an exceptional one, on the coast of New Jersey, where a surface well is still utilizable. The time will come when such supply can no longer be resorted to, but in this case it has not yet arrived.

PERSIFOR FRAZER.

THE ELECTROLYTIC METHOD AS APPLIED TO PALLADIUM.

BY EDGAR F. SMITH AND HARRY F. KELLER.

[*Read at the Stated Meeting of the Chemical Section, March 18, 1890.*]

Our knowledge bearing upon the behavior of this metal towards the current is limited and rather indefinite. In 1868, Wöhler published, in the *Annalen*, **143**, 375, an article entitled, "Ueber das Verhalten einiger Metalle im elektrischen Strom," from which the following facts are taken: Palladium, as the positive pole of a battery, consisting of two Bunsen cells, was immersed in water acidulated with sulphuric acid, when the metal immediately became coated with a deposit having a bright steel-like color. This deposit is doubtless palladium dioxide, as it liberates chlorine when treated with hydrochloric acid, and carbon dioxide when warmed with oxalic acid. At the same time, black, amorphous metal separated upon the negative pole. Its quantity was slight. In the second edition of *Classen's Quantitative Electrolysis*, p. 72 (American edition), it is stated that a feeble current will deposit palladium in a beautiful metallic state from an acid solution. One Bunsen cell is given as sufficient for this purpose. A more energetic current produces a spongy deposit. Ludwig Schucht has communicated* that from an aqueous solution of palladious nitrate, acidulated with a few drops of nitric acid, the current precipitated upon the negative pole a bronze-colored deposit, which, as it grew more dense, became darker, and finally black in color. At the positive pole there was a simultaneous deposition of oxide, showing a reddish color. In alkaline palladic solutions the precipitation of metal was much retarded; the deposition of oxide was also observed.

Our first experience in the electrolysis of palladium salts was acquired from the double cyanide in an excess of potas-

* Berg- und Hüttenmännische Zeitung **38**, 121; also, Zeit. für anal. Chem., **22**, 240.

sium cyanide. In such solution a current, generating one cc. oxyhydrogen gas per minute, failed to cause metallic deposition until after the expiration of thirty-six hours; in other words, not until the excess of potassium cyanide had been completely converted into alkaline carbonates. Then the deposit was black in color, but the precipitation was not at all complete. No deposition of oxide was noticed upon the positive pole. The conduct of the metal in cyanide solution led to the trial of certain separations, the results of which will be given in a later communication. The action of the current (feeble) was also tried upon a solution of palladious chloride, in the presence of a large excess of potassium sulphocyanide. In this case the deposition of metal was exceedingly rapid. Spongy spots were noticeable. The deposit was black in color. The experiment was made with this solution in the hope that possibly a separation of copper from palladium might be found; but, as these metals separate with equal rapidity from their sulphocyanides, the results are valueless for this purpose.

The next attempt was made with palladammonium chloride, $Pd(NH_3)_2Cl_2$, in just sufficient ammonium hydroxide to retain it in solution. The total dilution of the solution was 125 cc.; the acting current gave 0·9 cc. OH gas per minute. The poles were distant from each other about two inches. Just as soon as the circuit was completed, a yellowish-brown coating appeared upon the spiral of the positive pole; while upon the dish, in connection with the negative pole, a deposit of metal closely resembling the platinum itself in color made its appearance. After acting through the night the current was interrupted, the metal deposit carefully dried and weighed. The precipitation was incomplete. It was, however, discovered that the deposition at the positive pole, which gradually increased in mass and assumed a black color, had entirely disappeared. In all instances where the ammonium hydroxide was in decided excess, the precipitation of oxide on the positive pole was not observed. This behavior is similar to that of nickel when its ammoniacal solutions are electrolyzed. In subsequent experiments the course was somewhat modified. From solutions such as

just described, the palladium thrown out upon the platinum dish was extremely slow in dissolving, even in fuming nitric acid, so that it was deemed expedient to first coat the platinum dishes employed in the electrolysis with a layer of silver, varying in weight from 0·1 to 0·3 gram. This was done in the experiments recorded below, and was found to be decidedly advantageous. The layer of silver seemed to hasten the deposition of the palladium.

EXPERIMENT I.

A quantity of palladammonium chloride (= 0·2228 gram Pd) was dissolved in ammonium hydroxide; to this solution were added 20 to 30 cc. of the same reagent (sp. gr. 0·935) and 75 cc. water. The current allowed to act upon this ammoniacal liquid gave 0·9 cc. oxyhydrogen gas per minute. The decomposition continued through the night. At no time was there any oxide deposition upon the anode. The palladium gradually assumed a bright metallic appearance. After drying, the deposit showed about the same appearance as is ordinarily observed with this metal in sheet form. The washing was limited to hot water, and when the deposit was perfectly dry, the dish containing it was covered with a watch glass and exposed to a temperature ranging from 110° to 115° C. This was done to expel any hydrogen that might possibly have been retained by the palladium.

Weight of silvered dish + Pd = 61·9575 grams.
" " " — Pd = 68·7350

0·2225 Pd.

EXPERIMENT II.

In every respect similar to Experiment I, gave

Weight of silvered dish + Pd = 71·9540 grams.
" " " — Pd = 71·7315

0·2225 Pd.

The filtrates from these deposits were warmed for eight hours with ammonium sulphide without showing any formation whatever of palladium sulphide.

In several experiments, with conditions unlike those just described, and where consequently an incomplete precipita-

tion of metal occurred, the digestion with ammonium sulphide produced in every instance, in a very short time, a reddish-brown flocculent sulphide, carrying with it quite a considerable quantity of free sulphur.

In a second series of two experiments, in each of which there was the same amount of palladium as in the previous trials, the quantity of ammonium hydroxide in excess was made 30 cc., while the current (giving 0·8 cc. oxyhydrogen gas per minute) was allowed to act for sixteen hours. The results were quite concordant:

EXPERIMENT III.

Weight of silvered dish + Pd =	72·1055
" " " — Pd =	71·8825
Weight Pd =	0·2230 gram.

EXPERIMENT IV.

Weight of silvered dish + Pd =	62·0512
" " " — Pd =	61·8280
Weight Pd =	0·2232

It may be remarked that in filling the silvered platinum dishes a rather large surface of silver was allowed to remain above the electrolyzed liquid, so that by merely adding water it was possible to ascertain when the palladium was fully precipitated. When the deposition was not finished the new silver surface soon showed streaks of metal.

A third series of two experiments, in which the added amount of palladium was double that recorded in the preceding examples, the same conditions were observed as before, with the exception that as the current was only giving 0·70 cc. oxyhydrogen gas per minute, the time of precipitation was extended to eighteen hours. The results were as follows:

EXPERIMENT V.

Weight of silvered dish + Pd =	72·3555
" " " — Pd =	71·9100
Weight Pd =	0·4455

EXPERIMENT VI.

Weight of silvered dish + Pd =	62·2600
" " " — Pd =	61·8138
Weight Pd =	0·4462

Curiously enough, upon warming the liquid poured off from the palladium in Experiment V, with ammonium sulphide there appeared a very slight sulphide precipitate after some hours. The liquid from Experiment VI showed no trace of unprecipitated metal.

The deposits in the experiments just recorded were bright, metallic and very dense. In none was there the slightest tendency to sponginess. To show the accuracy of the method, the results may be tabulated as follows:

Experiment.	*Found Pd.*	*Calculated Pd.*
I,	0·2225	0·2228
II,	0·2225	0·2228
III,	0·2230	0·2228
IV,	0·2232	0·2228
V,	0·4455	0·4456
VI,	0·4462	0·4456

If the percentage differences be calculated, it will be found that they are quite within the limit of error occurring in almost any ordinary gravimetric determination.

The behavior of ammoniacal palladium solutions, when exposed to the action of the electric current, will be further studied as time permits, and, if possible, the attempt will be made to re-determine the atomic weight of the metal by this method in a somewhat modified form.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, February 12, 1890.

NOTES AND COMMENTS.

CHEMISTRY.

INDIAN INDUSTRIAL PRODUCTS—*Jour. Soc. Chem. Industry*, **9**, 670.—The following information respecting dyes and tanning materials and lac are extracted from a memorandum on Indian inland trade compiled in the Revenue and Agricultural Departments of the Government of India, and which has recently been issued from the Government central printing office at Simla.

Dyes and *tans* comprise indigo, myrabolans, cutch, turmeric, aniline dyes, and "others." The first is by far the most important, and stands at 323 lakhs of rupees* in a total trade in dyes and tans valued at 442 lakhs of rupees.

* A lakh of rupees = 100,000 rupees.

Bengal, the Northwestern Provinces, and Oudh and Madras, are the principal sources of commercial indigo, and their combined exports during the year amounted to 289½ lakhs of rupees, viz: Bengal 187½, Northwestern Provinces and Oudh seventy-three and one-half, and Madras twenty-eight and one-half lakhs of rupees. It is also grown rather extensively in the Punjab, but chiefly for local consumption. Elsewhere its cultivation is not unknown, but it is unimportant.

Indigo manufacture in Bengal has a long history, marked by many vicissitudes of fortune; but notwithstanding some serious checks, and, in later years, the competition of aniline and other dyes, it continues to hold its place as one of the great industries of the province. The total area under indigo in Bengal is estimated to be 588,000 acres, and the manufacture is in the hands of European capitalists. The season was fairly prosperous, and the exports amounted to 90,616 maunds.

In the Northwestern Provinces and Oudh, where canal irrigation is used, the average area under indigo is about 337,000 acres. Unlike Bengal, the manufacture is, except in the eastern districts, in the hands of natives.

The crop of 1888–89 was not a good one, owing to heavy rains, and exports fell from 43,000 maunds in 1887–88 to 40,000 maunds.

Madras indigo is commercially less valuable than that of Northern India. The area under cultivation amounts to between 400,000 and 500,000 acres. The exports were 23,866 maunds, against 26,000 maunds in the preceding year.

Myrabolans, the fruit of a species of *Terminalia*, are exported principally from the forests of the Central Provinces and Bombay to Bombay town. During the year the exports of the Central Provinces amounted to 5·31 lakhs of rupees in value, and of the Bombay Presidency to 3·34 lakhs of rupees.

The Indian trade in cutch is insignificant compared with that of Burma, and the total value was under eight lakhs of rupees.

Turmeric, the roasted root-stock of *Curcuma longa*, is a condiment as well as a dye, and is extensively used by the natives and Anglo-Indians for this purpose. The principal localities of production are Bengal, Madras, and the Northwestern Provinces and Oudh. The total export amounted to fifteen and one-half lakhs of rupees.

The growing popularity of aniline dyes is illustrated by the general distribution of the imports by sea among the internal trade blocks.

Lac.—Of the three commercial products of the insects, *Coccus lacca*, which cause the secretion of this resin, viz: stick-lac, shell-lac and lac-dye, the trade in the two former only is separately recorded. Lac-dye, which is obtained from the washing of stick-lac, and is a coloring matter derived from the female insect, imbedded in the resinous secretion, has, since the introduction of chemical dyes, almost disappeared as an article of export. Stick-lac is the crude product incrusting the twigs on which it is formed, but has, it is to be feared, been confounded in the returns in some instances with the manufactured article. Shell-lac is the pure resin extracted from stick-lac, which is pounded and exposed to heat for the purpose. *Coccus lacca* has a wide distribution and affects various trees, but is collected principally from

two or three species of fig. The jungles of the Central Provinces are the chief sources of supply. In Assam the insect is regularly cultivated on two varieties of fig. The inland trade this year is valued at 101 lakhs of rupees.

H. T.

GAMBIER AT SINGAPORE—Annual report of Singapore Botanical Gardens; through *Jour. Soc. Chem. Industry*, **9**, 670.—Gambier is one of the most important products of Singapore, but, although it still maintains its high price, there are many complaints from England that the imported article is heavily adulterated with water. In order to trace the origin of this excess, samples taken from the field fresh from the boiling-shed were sent to Mr. Evans, of Bristol, whose analysis, as compared with a sample of block-gambier received by him in the ordinary course of trade, was as follows:

	Gambier from the Field. per cent.	*Trade Gambier.* per cent.
Tannin,	11·48	14·68
Organic matter,	30·11	42·26
Water,	53·39	31·89
Ash,	4·46	6·34
Loss,	0·56	4·48
	100·00	99·65

The result shows that there is actually less water in the trade article than in the gambier taken directly from the coolies' hands, and negatives the suggestion that the town *Towkay* adulterates the gambier, after receiving it in Singapore, with water to make it heavier. The other suggestion that the gambier has deteriorated of late years from insufficient inspiration, owing to less fuel being used in boiling, seems more probable. In earlier years, when there was no attempt made to protect the forests, the destruction of firing was very large, and fuel could be had in large quantities. Now the results of this wasteful destruction are being felt, and the gambier is insufficiently boiled and dried.

Persons interested in the trade recently conceived the idea of forming a company in Singapore to cultivate gambier on a large scale, but this has fallen through, and there is an idea that this product may be cultivated more profitably, that is with European labor, in other of our colonies. Consequently, most botanical establishments have applied to the Singapore gardens for seeds or young plants, and a large quantity of seed was carefully collected, dried, and distributed widely, but, as far as has yet been heard, the experiments with it have failed entirely. It seems now certain that gambier seed has a very short duration of life (the Chinese say only twenty-four hours)—that is, it must be sown as soon as ripe. Thus, all attempts to send seed to distant colonies must prove futile. Unfortunately, too, young plants are very bad travellers, and though many have been sent out to different establishments, few appear to survive the voyage. More plants, in as healthy a condition as possible, are now to be sent out to various colonies where gambier is likely to thrive.

H. T.